The Effects of Work Stress, Passive Smoking, Negative Affect, Coping Ability and Other Lifestyle Factors on the Sick Building Syndrome

Dr. Alan Hedge & Dr. Gary Evans

Researcher: Ceiling Tiles May Cause Majority of SBS

A Cornell University study, led by Alan Hedge, has tentatively concluded that flaking particles from ceiling tiles made of glass wool may be a major contributor to Sick Building Syndrome.

What this means to building operators, Hedge said, is that tiles with fiberglass and other glass wool ingredients should not be bought in the first place. If tile with glass wool ingredients are already installed, proper office cleaning can reduce exposure to the harmful particles.

The study, *Effects of Man-Made Mineral Fibers in Settled-Dust on Sick Building Syndrome in Air-Conditioned Offices*, is the second major research report recently to conclude that thorough office cleaning may mitigate SBS.

Earlier this year, British researchers at the United Kingdom Building Research Establishment, Watford, U.K., published their findings, which concluded that indoor surface pollution, such as dust, fibers and microorganisms deposited in or on surfaces in buildings may cause SBS (see *IPN* Oct. 15, Vol. 6, No. 21, p 165). They, too, recommended thorough office cleaning to mitigate the impact of dust and other particles.

The amount of mineral fibers in settled dust correlates with the number of SBS symptoms reported by workers. In other words, the higher the mineral dust concentration, the greater number of workers' complaints. Dust that causes problems comes from flaking ceiling tiles, which are friable in the grids of false ceilings, Hedge said.

False Ceiling Used as Plenums

The glass wool tiles flake easily because in newer office buildings return air ducts for the heating, ventilating and air-conditioning systems have been eliminated and the plenum, the space between the false ceiling and floor above, serves as a return air corridor. The returning air, as well as noise vibrations, maintenance work, and other disturbances, such as tiles becoming damp, causes flaking and the release of harmful particles, Hedge explained.

The glass wool fibers are an eye and lung irritant and may also serve as a carrier for other pollutants, such as tobacco smoke, volatile organic compounds, formaldehyde, among other things. "Just look at the instructions for mineral fiber ceilings. They say avoid breathing in the material and avoid contact with skin." Ceiling installers display SBS-type symptoms, but when they are away from the job those symptoms generally clear up, Hedge said.

Tobacco Smoke Ruled Out

The study also ruled out a number of culprits, such as tobacco smoke and VOCs, that have been traditionally blamed for SBS. "Although many people assume that Sick Building Syndrome is related to gaseous air pollutants, many studies, including ours, have been unable to find the link."

They found no relationship between the number of workers' complaints and indicators of air quality such as carbon monoxide, formaldehyde, temperature, humidity or the air's staleness. Employees did not report more SBS style symptoms in buildings where their co-workers smoked.

There also may be a psychological factor involved in SBS complaints. People are not biologically equipped to detect air quality, such as relative humidity, carbon monoxide, radon, and many other gases. Office workers make decisions about air quality based on smell, temperature, air movement, and their perception of humidity, and visible dust. These visual triggers coupled with colleagues reports that the building made them sick, and if investigators wearing protective masks are prowling the building's offices, that combination of factors could make other employees feel that the building is making them sick, too.

Range of Susceptibility

There is clearly a range of susceptibility to SBS-stlye illness and "people are not lying, they are reporting what they are feeling, but that doesn't necessarily correlate with what they are exposed to," Hedge said.

However, after an SBS incident, people begin to distrust the building, Hedge said, drawing an analogy of a homeowner who has been burglarized and never again feels fully comfortable in his house.

Besides thorough cleaning, using high filtration vacuum bags, bags that can filter and contain particles as small as one micron, air can be cleaned at each work station with devices that use activated charcoal and HEPA filters.

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R: REDACTED MATERIAL

CENTER FOR INDOOR AIR RESEARCH
1099 WINTERSON ROAD SUITE 280 LINTHICUM, MD. 21090
(410) 684-3777 FAX (410) 684-3729

APPLICATION FOR RESEARCH CONTRACT

1. PRINCIPAL INVESTIGATOR: NAME, TITLE, TELEPHONE # AND MAILING ADDRESS:

(A) Alan Hedge (NAME) (B) Assoc. Prof. (TITLE) (C) 607-255-1957/255-0305 (TELEPHONE #/ FAX #)

(D) Design & Environmental Analysis (DEPARTMENT) (E) Cornell University (INSTITUTION)

(F) E104 Martha Van Rensselaer Hall (MAILING ADDRESS) (G) Ithaca, NY 14853-4401 (STATE/ZIP)

2. PROJECT TITLE The Effects of Work Stress, Passive Smoking, Negative Affect, Coping Ability and Other Lifestyle Factors on the Sick Building Syndrome

3. KEY WORDS. PLEASE PROVIDE THREE (3) KEY WORDS WHICH WILL BE USED AS REFERENCE HEADINGS. SBS, Indoor, Stress

4. INSTITUTION. NAME AND ADDRESS OF INSTITUTION RESPONSIBLE AND ACCOUNTABLE FOR DISPOSITION OF FUNDS AWARDED ON THE BASIS OF THIS APPLICATION.

(A) Cornell University (INSTITUTION) (B) Office of Sponsored Programs, 130 Day Hall (STREET ADDRESS)

(C) Ithaca (CITY) (D) New York 14853-4401 (STATE/ZIP)

5. LOCATION. LIST LOCATION WHERE RESEARCH WILL BE CONDUCTED IF OTHER THAN INSTITUTION IDENTIFIED IN #4 ABOVE.

(A)

(B)

6. INCLUSIVE DATES AND TOTAL COSTS OF THIS SPECIFIC PROJECT RELATED TO EACH 12 MONTH PERIOD IF MORE THAN ONE YEAR IS REQUIRED TO COMPLETE PROJECT. SUMMARIZE FROM BUDGET PAGE, ITEM 12(J). IT MUST BE UNDERSTOOD THAT AWARDS FOR 2ND AND 3RD PERIODS ARE DEPENDENT ON CENTER APPROVAL OF CONTINUATION APPLICATION.

	INCLUSIVE DATE			
(A) 1ST 12 MONTH PERIOD	1/1/94	THRU 12/31/94	$	REDACTED
(B) 2ND 12 MONTH PERIOD IF REQUIRED	1/1/95	THRU 12/31/95	$	
(C) 3RD 12 MONTH PERIOD IF REQUIRED	1/1/96	THRU 12/31/96	$	

7. INSTITUTIONAL OFFICER. NAME, TITLE AND TELEPHONE NUMBER OF INDIVIDUAL AUTHORIZED TO SIGN FOR THE INSTITUTION IDENTIFIED IN #4 ABOVE. IT IS UNDERSTOOD THAT THE OFFICER, IN APPLYING FOR A CONTRACT, HAS READ AND FOUND ACCEPTABLE THE CENTER'S MANAGEMENT OF RESEARCH CONTRACTS AND CONTRACT ADMINISTRATION POLICY.

(A) Denise Clark (NAME) (B) Grant/Contract Officer (TITLE)

(C) (607)255-5014 (TELEPHONE) (D) ______ (SIGNATURE OF INSTITUTIONAL OFFICER) (E) ______ (DATE)

8. PRELIMINARY STUDIES*:
(A) FEASIBILITY OF PROPOSED RESEARCH
(B) QUALIFICATIONS OF INVESTIGATOR

9. EXPERIMENTAL PLAN*.
(A) DESIGN
(B) METHODS
(C) ANALYSIS OF DATA
(D) INTERPRETATION OF RESULTS
(E) TIMETABLE FOR THE INVESTIGATION
(F) LITERATURE CITED

10. AVAILABLE FACILITIES AND RESOURCES.

11. OTHER SUPPORT

* APPEND AS MUCH MATERIAL AS REQUIRED. TYPE, SINGLE SPACE, USE 8-1/2" X 11" WHITE PAPER AND LABEL EACH SHEET WITH NAME OF THE PRINCIPAL INVESTIGATOR IN THE UPPER RIGHT HAND CORNER AND PAGE NUMBER AT THE BOTTOM. CONSECUTIVELY NUMBER EACH ADDENDUM BEGINNING WITH PAGE 5. DO NOT INSERT PAGES BETWEEN PAGES 1 AND 6, E.G., 2A, 2B, 3A, ETC. INCLUDE NINE COPIES AND AN ORIGINAL. IF SENDING PHOTOGRAPHS, INCLUDE 2 ORIGINAL SETS. NOTE: EACH OF THE NINE COPIES *MUST* BE PLACED IN A BINDER PER MAILING INSTRUCTIONS.

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13. BIOGRAPHICAL SKETCH of all professional personnel listed in 12(a). Append. Please include the following: Name, title, education, scientific field, major research interest, research and/or professional experience and publications. (Limit list of publications to the 20 most important and/or relevant.)

14. a) Are HUMAN SUBJECTS to be used in this research? X Yes ____ No
If yes, attach Institutional Review Board approval for procedures involving human subjects.

b) Are LABORATORY ANIMALS to be used in this research? ____ Yes X No
If yes, attach Institutional Animal Care and Use Committee approval for procedures involving animals.

15. SIGNATURE OF PRINCIPAL INVESTIGATOR: It is understood that the applicant in applying for a Contract has read and found acceptable the Statements of Policy and Terms Under Which Project Contracts Are Made appearing in the application package.

Alan Hedge 5/25/93

Signature of Principal Investigator Date

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CORNELL
UNIVERSITY

University Committee on Human Subjects

120 Day Hall
ae 255-5014

To be included in grant proposal for Hedge & Evans.

MEMORANDUM

TO: Alan Hedge

FROM: Dennis Regan, UCHS Chairman Dennis Regan /ar

DATE: May 21, 1993

RE: ***The Effects of Work Stress, Passive Smoking, Negative Affect, Coping Ability and Other Lifestyle Factors on the Sick Building Syndrome***

The University Committee on Human Subjects, under its summer operating procedures, has reviewed and approved the above referenced proposal as far as the use of human subjects is concerned.

This proposal will be reviewed by the committee as a whole at its next formal meeting. Should any members have questions or require additional information concerning your proposal, it is expected that you will provide them.

This approval shall remain in effect for a period of one year. All ongoing projects involving the use of human subjects should be resubmitted to the Human Subjects Committee for review on an annual basis or whenever there are changes in the protocol as originally approved.

c: -----
UCHS file

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RESEARCH ABSTRACT

Title of Project: THE EFFECTS OF WORK STRESS, PASSIVE SMOKING, NEGATIVE AFFECT, COPING ABILITY AND OTHER LIFESTYLE FACTORS ON THE SICK BUILDING SYNDROME.

Investigator(s): Dr. Alan Hedge, Dr. Gary Evans

Institution: Cornell University

ABSTRACT: In the space below, please provide a descriptive summary of your proposed research project.

Associations between symptoms of the sick building syndrome (SBS), work stress, passive smoking, negative affect, ability to copy with stress, and other lifestyle factors will be tested in a cross-sectional self-report questionnaire survey of some 2,000 workers from 4 smoking prohibited and 4 smoking restricted offices. In addition, a preliminary study of associations between the self-report measures used in the survey, diary records, and urinary catecholamines, cortisol, and cotinine will be conducted. The preliminary study will be followed by a longitudinal case-control study of 100 workers selected from one of smoking restricted and smoking prohibited buildings. Selected cases (n=50) will have 4 or more symptoms of SBS, selected controls (n=50) will be free of SBS symptoms. Subjects will be surveyed every three months for one year. Associations between symptom status, self-reported stress and ETS exposure, individual variables, and urinary biomarkers of work stress and passive smoking will be tested in each wave. Seasonal and temporal influences on SBS symptoms will be tested. The results of this research will elucidate whether associations between work stress, passive smoking, and the SBS arise because of physiological changes which might modify individual susceptibility to indoor air pollutants.

G. Evans
Alan Hedge
Signature, Principal Investigator

5/31/93
Date

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THE EFFECTS OF WORK STRESS, PASSIVE SMOKING, NEGATIVE AFFECT, COPING ABILITY AND OTHER LIFESTYLE FACTORS ON THE SICK BUILDING SYNDROME.

SPONSORED PROGRAM PROPOSAL
to the Center for Indoor Air Research,
1099 Winterson Road, Suite 280,
Linthicum, Maryland 21090.

Submitted by
CORNELL UNIVERSITY
Office of Sponsored Programs
123 Day Hall
Ithaca, New York 14853

PROJECT DIRECTORS: Alan Hedge

Alan Hedge, Ph.D., Associate Professor

Gary Evans, Ph.D., Professor
Dept. Design & Environmental Analysis

TOTAL FUNDS REQUESTED: $________

PROJECT PERIOD: January 1, 1994 - December 31, 1996

UNIVERSITY APPROVAL

Denise Clark
Grant and Contract Officer
Office of Sponsored Programs

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PRELIMINARY STUDIES

Characteristic symptoms of the Sick Building Syndrome (SBS)

The sick building syndrome (SBS) comprises a collection of symptoms of eye, nose and throat irritation, sensations of dry mucus membranes and skin, erythema, mental fatigue, headache, hoarseness, itching, unspecific hypersensitivity, cough, high frequency airway infections, wheezing, dizziness, and nausea, all of which are associated with the occupancy of certain buildings (W.H.O., 1983). Sometimes definitions of the SBS may also include odor or taste complaints (Mølhave, 1989). Each of these symptoms is relatively commonplace among the general population, but SBS is characterized by these symptom reports being more prevalent among workers in certain buildings, by workers only developing these symptoms after entering their workplace, by symptoms being alleviated when workers are away from their workplace, and by an absence of objective signs of infection, (e.g. elevated temperature). For these reasons, SBS symptoms are distinguishable from those of building-related illnesses, such as Legionnaire's disease, which normally persist, and may even worsen, after leaving the building, and which show physical signs of illness.

In recognition of the diverse array of possible causes of symptoms, the World Health Organization (1983) called for a distinction between "temporary" SBS and "permanent" SBS. Temporary SBS describes cases where an acute outbreak of symptoms among workers follows an identifiable trigger event, e.g. installation of new carpet, newly painted walls, re-tarring of a roof, etc., and elevated levels of chemical pollutants, especially volatile organic compounds, may be responsible for transient irritation symptoms. Permanent SBS describes situations where indoor air quality, according to measures of gaseous pollutants, does not appear to be problematic, but SBS symptoms are widespread and chronic among workers. The W.H.O. recognized that psychosocial factors may play an important role in the etiology of permanent SBS. However, researchers generally have ignored this important distinction, and considerable research has been focused on identifying the indoor air pollutant(s) responsible for causing the SBS. Research studies conducted worldwide over the past decade generally have failed to find consistent patterns of significant correlations between gaseous indoor air pollutants and permanent SBS among workers in office buildings.

The SBS, building ventilation, and indoor climate

In air-conditioned buildings the supply air may pass through several potential sources of contamination, (e.g. ducts, chiller, humidifier) whereas in naturally ventilated buildings ventilation depends solely on operable windows and natural infiltration. Consequently, several studies have

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investigated building ventilation and indoor climate factors which might cause permanent SBS. Several studies have shown that SBS symptoms are more prevalent among workers in air-conditioned buildings than those in naturally ventilated buildings (e.g. Burge *et al.*, 1987; Finnegan *et al.*,1984, 1987, 1990; Mendell and Smith, 1990). Hedge (1984a,b) administered a questionnaire survey in 6 office buildings and found that the prevalence of eye, nose, and throat symptoms was higher in the air-conditioned offices than the naturally ventilated offices. However, reports of headache did not differ between offices as a function of type of ventilation, although they were more prevalent in deep, open-plan office spaces than in private offices. He also found that symptoms were significantly more prevalent among women than men in the offices. Numerous studies have confirmed this gender difference in symptom prevalence, (e.g. Hedge *et al.*, 1989a,b; Hedge *et al.*, 1992,1993a,b; Kleven and Sterling, 1989; Tamblyn and Menzies, 1992). Norbäck (1990) suggests that gender differences in symptoms may be attributable to differences in allergy between men and women, although Hedge *et al.* (1992) have shown that allergy does not account for differences in SBS prevalence among 3,155 U.S. office workers.

A nationwide questionnaire survey of 4,373 office workers in 47 office sites in the U.K. confirmed that SBS was more prevalent in air-conditioned than in unconditioned offices (Burge *et al.*, 1987; Wilson and Hedge,1987), but this study also showed that in some kinds of mechanically ventilated buildings (i.e., those with ducted air or forced air extract but with no air-conditioning), symptoms were less prevalent than in naturally ventilated buildings, which previously had been thought to be the healthiest type of offices. Symptoms were more prevalent in buildings with air conditioning, but contrary to expectations, among these air-conditioned buildings symptoms generally were less prevalent in variable air volume (VAV) HVAC systems, which re-circulate a greater proportion of aged office air, than in either HVAC systems with ceiling induction or fan-coil units (where air is ducted from a central plant room and then either heated or cooled in the room). The worst buildings tended to be those with local HVAC systems with no ducting, where air is directly supplied to the office from the outside by wall-mounted units without any ducts, (e.g. Versatemp systems). Unfortunately, these U.K. surveys did not include any measures of the physical environment conditions, and so the extent to which symptoms were associated with exposure to polluted indoor air cannot be established. However, a follow-up survey of 9 of these buildings conducted some 2 years later which incorporated physical environment measures (air and radiant temperatures, relative humidity, illumination, dBA sound levels, carbon dioxide, ventilation rate, and air velocity) failed to find environmental correlates of symptoms (Wilson *et al.*, 1987).

Robertson *et al.* (1985) compared SBS symptom reports for government workers in adjacent air-conditioned and naturally ventilated office buildings. SBS symptoms were more prevalent among workers in the air-conditioned offices than among their counterparts in the naturally

ventilated offices, although measurement of a variety of physical environmental parameters (air temperature, globe temperature, air velocity, negative and positive air ion concentrations, formaldehyde, carbon monoxide, and ozone) failed to show any significant differences in the environmental conditions between the buildings. Hedge *et al.* (1989b) also compared symptom reports for municipal office workers in adjacent air-conditioned and naturally ventilated office buildings, and similarly found that SBS symptoms were more prevalent in the air-conditioned buildings, but apart from slightly higher concentrations of volatile organic compounds in the air-conditioned building, indoor air quality measures were comparable in the two buildings. However, a significant association was found in both buildings between formaldehyde and reports of leaving work early because of feeling unwell.

A Danish survey of 4,369 office workers in 14 Danish town halls and 14 associated office buildings examined physical conditions, indoor air pollutants, and SBS. Results showed considerable variation in the prevalence of SBS among buildings, and initially no difference in symptom prevalence between mechanically ventilated and naturally ventilated buildings was reported (Skov, Valbjørn, and DISG, 1987), although recent re-analysis of this work (Mendell and Smith, 1990; Skov *et al.*, 1990), has revealed that SBS symptoms were more prevalent in the air-conditioned buildings. Symptoms were not correlated with any of the indoor air pollutants which were measured, but they were correlated with a fleece factor (the area of material surface divided by the room volume), a shelf factor (the area of open-shelving divided by the volume of the room), and the total dust or macromolecular organic dust (the biological fraction of dust).

A survey of 7,043 Dutch office workers in 61 buildings found that the prevalence of SBS symptoms was higher in air-conditioned buildings than in naturally ventilated or mechanically ventilated buildings, but associations between indoor climate variables and symptoms were weak and inconsistent, and there was no significant effect of a fleece or shelf factor (Zweers *et al.*, 1990, 1992).

Studies of a Finnish office building suggest that the total number of SBS symptoms and increasing air temperature above 22°C may be linearly related (Jaakkola *et al.*, 1989), but varying the ventilation rate between 3.5 cfm per person and 35 cfm per person does not affect symptoms (Jaakkola *et al.*, 1987, 1991). Ventilating a building with either 100% outdoor air or 25% outdoor air has little effect on the prevalence of SBS symptoms (Jaakkola *et al.*, 1990; Sterling and Sterling, 1983). Increasing the ventilation rate from 20 cfm to 50 cfm apparently has no beneficial effects on SBS symptoms (Menzies *et al.*, 1993).

A survey of 4,479 workers in 27 U.S. office buildings found no association between indoor climate measures (carbon monoxide, carbon dioxide, formaldehyde, nicotine, respirable particles, illumination, air temperature and relative humidity) and the number of SBS symptoms reported

(Hedge *et al.*, 1993a,b). Nearly 4,000 federal workers in three office buildings were surveyed and results showed that symptom reports were correlated with perception of dust in the offices, although measures of dust were not taken, but psychosocial variables also affected symptom reports (Wallace *et al.*, 1991). A recent study of 1,324 workers from 9 buildings has found a relationship between SBS symptoms and the amount of man-made mineral fiber in settled office dust (Hedge *et al.*, 1993c), and an intervention study has shown that thorough office cleaning can significantly reduce the number of SBS symptoms reported by workers (Leinster *et al.*, 1990).

A few small scale studies have reported correlations between various physical environment measures and SBS symptoms. The environmental factors which have correlated with SBS symptoms include vibration from nearby mechanical ventilation equipment (Hodgson *et al.*, 1987), infrasound from the HVAC system (Hyde, 1989), and illumination (Hodgson and Collopy, 1989; Robertson *et al.*, 1989). Armstrong *et al.* (1989) investigated SBS symptoms in a high rise public office building and found that symptoms were associated with total suspended particulates but not with any other indoor air pollutants. However, in a study of 15 office buildings Harrison *et al.* (1990) have found a negative correlation between the number of SBS symptoms and total airborne particulates when data are analyzed across ventilation classes, but a positive correlation between total airborne particulates and SBS symptoms when data are analyzed within a ventilation class, and Hodgson and Collopy (1989) found that symptom reports decreased with increased respirable suspended particulates.

The SBS and individual and occupational factors

Studies have consistently linked the SBS to aspects of the type of ventilation system in the building, but no consistent associations between symptoms and physical environment measures have yet emerged. Studies have, however, found consistent associations between a variety of individual factors (gender, perceived control, attitudes to environmental conditions) and occupational factors (computer use, job stress, job dissatisfaction). The Danish study found that a worker's gender, whether or not the worker drank coffee at work, length of use of a VDT, work variety, and items of job dissatisfaction correlated with symptom reports (Skov *et al.*, 1989). U.K. studies have found that worker's gender, hours of computer use, job dissatisfaction, job stress, perceived environmental conditions, satisfaction with the environment, and personal control over the environment correlate with SBS symptoms (Hedge, 1988; Hedge *et al.*, 1989a). Other studies have confirmed these effects of job dissatisfaction (Hedge *et al.*, 1991, 1992; Tamblyn and Menzies, 1992; Zweers *et al.*, 1992), job stress (Hedge, 1988; Hedge *et al.*, 1991a,b, 1992; Hodgson *et al.*, 1992; Tamblyn and Menzies, 1992), and perceived poor environmental conditions (Hedge *et al.*, 1993;Tamblyn and Menzies, 1992). Norbäck *et al.* (1989) studied the prevalence of

SBS symptoms among different occupational groups: hospital workers and industrial workers who were exposed to airborne gaseous irritants, and office workers who, according to hygiene measures, were not exposed to comparable levels of these irritants. They found that SBS symptoms were more prevalent among the office workers even though chemical exposures were lower for this group. They also found that women reported more symptoms than men, but that individual factors (i.e., mean age, atopy frequency, and smoking habits), and occupational factors (i.e., work stress, work satisfaction) were not related to symptom reporting, although SBS symptoms were not defined as being work-related in this study.

An investigation of the role of psychosocial factors found that a self-report measure of psychopathology (Minnesota Multiphasic Personality Inventory) and a physical symptom checklist did not discriminate symptomatic workers (n=27) from asymptomatic workers (n=58) in a problem building, or differentiate these from a control group (n=26) taken from a nonproblem building (Bauer *et al.*, 1992). Similarly, a survey of 255 workers from 5 office buildings found no associations between SBS symptoms and personality dimensions (extraversion/introversion; neuroticism/stability; toughmindedness/tendermindedness) measured using the Eysenck Personality Questionnaire, depression as measured by the Beck Depression Inventory, individual differences in circadian rhythm as measured by the Morningness-Eveningness questionnaire, and vulnerability to stress and general life stressors as measured by the Stress Audit, although there was a weak effect of self-reported seasonal affective disorder (Hedge *et al.*, 1993a). Psychological variables may trigger or maintain patterns of symptom reporting and these must be considered in investigations of the SBS (Ryan and Morrow, 1992).

The SBS, environmental tobacco smoke, and passive smoking

Environmental tobacco smoke (ETS) frequently is cited as a significant source of indoor air pollution and as a major risk factor for heart disease and lung cancer (Samet *et al.*, 1987). Involuntary inhalation of ETS by nonsmokers, termed passive smoking, also has been cited as a workplace hazard responsible for acute mucus membrane irritation symptoms and also more serious, chronic health effects (Pershagen, 1986; U.S. Surgeon General, 1986; Douville, 1990; Woodward, 1991). Some case-control studies of SBS have reported that active smoking is a risk factor (Bauer *et al.*, 1992; Menzies *et al.*, 1992), while others have not confirmed this (Tamblyn and Menzies, 1992). However, all of these case-control studies have found that passive smoking is a risk factor for the SBS. Conversely, most large cross-sectional surveys of office workers generally have failed to find that either active or passive smoking is a significant risk factor for the SBS (Hedge *et al.*, 1990,1992; Skov *et al.*, 1989; Zweers *et al.*, 1992), although some studies have reported associations (Norbäck *et al.*, 1990; Robertson *et al.*, 1988; Jaakkola *et al.*, 1991),

and exposure to ETS is often cited as a significant risk factor for the SBS (e.g., Levy and Maroni, 1992).

Results currently in preparation for publication obtained by Hedge show that although there is no effect of passive smoke exposure on the number of SBS symptoms reported by workers, the prevalence of symptoms of sore, irritated eyes and throat, and stuffy congested nose is elevated by about 10% for nonsmokers involuntarily exposed to ETS at work for 3 or more hours per day. Unfortunately, all of these studies have used self-reports of passive smoking which cannot yield quantifiable estimates of ETS exposure. Nevertheless, in view of fears about the health effects of active and passive smoking, many companies have introduced policies which restrict or prohibit smoking at work in an attempt to improve indoor air quality and lower SBS complaints. A field experimental study of 5 different smoking policies has shown that compared with ad lib smoking at workstations, prohibiting or spatially restricting smoking in large office buildings has little beneficial effect on ETS pollutant concentrations and no significant effect on SBS reports (Hedge *et al.*, 1993).

In a highly critical review of epidemiological studies of the health effects of active and passive smoking, Eysenck (1991) concludes that "psychosocial variables, and in particular personality type and stress, are important in mediating deaths from cancer and coronary heart disease. These personality variable are more influential than physical factors like smoking, blood pressure, and cholesterol, in the ratio of roughly 6:1 for the groups here studied." (p. 64). Other recent work on sickness absence among office workers (North *et al.*, 1993) shows slightly elevated risk ratios for smokers than nonsmokers for both short (RR = 1.46 for men and 1.09 for women) and long spells of sickness absence (RR = 1.81 for men and 1.37 for women). However, results showed that other psychosocial factors yielded similar if not higher risks, such as job control which affects risks of short (RR = 1.58 for men and 1.21 for women) and long spells of sickness absence (RR = 1.54 for men and 1.52 for women), and work variety and use of skills affects risks of short (RR = 1.72 for men and 1.41 for women) and long spells of sickness absence (RR = 1.82 for men and 1.69 for women). Personal characteristics, such as self-rated health, produced the greatest increases in relative risks for both short (RR = 1.78 for men and 1.56 for women) and long spells of sickness absence (RR = 2.36 for men and 2.16 for women). Norbäck *et al.* (1990) have found that sick leave due to respiratory illness and hyperreactivity symptoms experienced outside of work are strongly correlated with the number of SBS reported.

<u>Summary of Current Knowledge on the Cause(s) of the SBS</u>

After more than a decade of research, the cause(s) of SBS remain elusive. It is generally assumed that the symptoms are causally related to occupancy of certain buildings, and that the

indoor air quality in the building is somehow responsible. To date, research investigations of SBS have reported diverse findings, but a pattern is emerging:

a. SBS is usually more prevalent in air conditioned/mechanically ventilated buildings than in unconditioned and naturally ventilated buildings.
b. SBS symptoms are experienced when sufferers are in the building but alleviated when sufferers are away from the building.
c. Investigations of buildings with a high prevalence of SBS have found that the symptoms generally are not correlated with ventilation rate, in fact symptoms may worsen as the ventilation rate is increased, nor do symptoms usually correlate with the concentration of specific gases, vapors, or microbiological contaminants in indoor air.
d. SBS sometimes correlates with air temperatures above 22°C.
e. SBS sometimes correlates with shelf and fleece factors, total particulate mass, and total VOCs.
f. SBS sometimes correlates with smoking status and with passive smoking.
g. SBS consistently is more prevalent among women than men, irrespective of differences in allergic sensitivity; among those who perceive their work environment conditions as unsatisfactory; among computer users; among those doing stressful work; among those dissatisfied with work.

The studies performed to date show that indoor air quality, as measured by concentrations of specific gases, vapors, or microbiological organisms, alone is not be responsible for the SBS. Like many complex illnesses, the causes of SBS appear to be multi-factorial (Hedge, 1989, 1990a) and psychosocial variables consistently play an important though ill-understood role.

Limitations with Current Investigations of SBS

A number of caveats need to be placed on the results from the studies of the SBS which have been briefly reviewed. First, SBS symptoms commonly have been measured using self-report questionnaires. Examination of the questionnaires used by different research groups shows that there has been considerable variability in questionnaire format, question phrasing, the range of symptoms investigated, whether or not symptoms have been defined as being work-related, and the time over which these have been experienced (Hedge, 1990b). For example, the questionnaire used by Robertson *et al*. (1985), Burge *et al*. (1987), Wilson and Hedge (1987), and Hedge *et al*. (1989a) asked workers to respond "Yes" or "No" to a question asking whether or not they had experienced each of ten symptoms on two or more occasions in the previous 12 months. Questionnaires used by Norbäck *et al*. (1990) and that used by Sterling and Sterling (1983) and Hedge *et al*. (1986, 1989b) do not define symptoms as being work-related. The questionnaires used by Skov *et al*. (1987) ask about the frequency of work-related symptoms (daily; weekly;

monthly; less often; never) over a shorter 6 month period whereas others look at periods varying from one week (e.g. Jaakkola *et al.*, 1991) to one year (e.g. Burge *et al.*, 1987). Only the questionnaire developed by Hedge *et al.* (1991a,b,1992,1993a,b,c) uses a common frequency scale for both environmental conditions and sick building syndrome symptoms.

Second, survey sampling methods in buildings have varied widely. Burge *et al.* (1987) administered questionnaires to random samples of about 100 workers in each of the buildings with the questionnaires distributed and collected on the same day by the researchers, whereas Hedge *et al.* (1989b) administered questionnaires to all workers in the building but these were returned via departmental representatives at the end of a one-week period. Also, in some studies the buildings were investigated because they were known to have problems (e.g., the air-conditioned buildings studied by Finnegan *et al.*,1984, Robertson *et al.* ,1985, and Hedge *et al.* ,1986, 1989b), whereas other studies have tried to study a more representative sample of buildings (e.g., Burge *et al.*, 1987; Hedge *et al.*, 1991a,b,1992,1993a,b,c).

Third, air quality variables usually have been measured at specific locations in a building and for relatively brief periods of time whereas the questionnaires typically have been widely administered throughout a building and have asked about symptoms over time periods considerably in excess of that for which air quality and other environmental data are available. Thus, neither spatial nor temporal variables closely correspond in these studies. It may be that the discrepancies in the measures and methods used by different researchers, and between the temporal and spatial bases for air quality and environmental measures compared with those for symptom reports, underlie the lack of consistent associations reported. The work of Hedge *et al.* (1992, 1993b) and Hodgson and Collopy (1989) are exceptions because they have studied temporo-spatial covariation in conditions and symptoms and have uncovered some relationships between air pollutants and specific symptoms, although these are only weak associations.

Fourth, although a number of factors have been shown to influence reports of SBS symptoms the mechanisms by which these might cause health effects are unknown. For example, it is highly unlikely that an air temperature above 22°C directly causes any of the SBS symptoms since such temperatures are commonplace in summertime but do not precipitate symptoms, or that stressful work of itself causes symptoms such as itching eyes, sore throat, or coughing. Rather, it is likely that these are indicators of other factors within the workplace which may cause symptoms. What then might be the physical trigger for many of the reports of SBS? With the exception of a U.K. study (Wilson and Hedge, 1987), which made a preliminary attempt at collecting building design data, epidemiological surveys of SBS largely have ignored the role of other architectural factors which usually are confounded with a building being air conditioned (e.g., deep floor plan, open-plan office layout, sealed windows, furniture, and acoustic ceilings).

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Fifth, although job stress is associated with the SBS, the nature of this relationship requires further investigation and elucidation. Job stress may of itself be a major etiological factor in the SBS. The biological changes which occur in a stressed person are know to influence immune function, and perhaps job stress influences SBS reports because of changes in an individual's susceptibility to environmental agents. Alternatively, the association between job stress and the SBS may be spurious and it may reflect the operation of one or more as yet unmeasured variables, such as negative affect.The role of job stress in the etiology of the SBS has yet to be thoroughly investigated.

PROJECT RATIONALE: DESIGN AND METHODS

The studies which have been reviewed generally have failed to find consistent correlations between gaseous indoor air pollutants and SBS symptoms among office workers, however, these studies consistently have found that personal, occupational, and psychosocial variables play a significant role in symptom reporting. There is also conflicting evidence for an association between passive smoking and at least some of the symptoms of the SBS in nonsmokers. The proposed research is a project which will use multiple methods to directly address these issues. The first phase of this research will involve a cross-sectional survey of office workers in smoking prohibited and smoking restricted buildings. The second phase will involve a longitudinal case-control study of biomarkers of stress and ETS exposure for SBS symptomatic and asymptomatic workers in a smoking prohibited and a restricted smoking building. Methodological details for this work are described below and an outline of the schedule for the proposed project is presented in Appendix 1.

PHASE 1: CROSS-SECTIONAL SURVEY

Phase 1 Aim: Conduct a cross-sectional survey of smoking prohibited and spatially restricted smoking buildings to investigate the effects of work stress, passive smoking, negative affect, ability to cope with stress, and other lifestyle factors on the sick building syndrome.

The first phase of the proposed research will involve conducting cross-sectional surveys of workers in 8 office buildings, 4 in which smoking is prohibited and 4 in which smoking is spatially restricted. One aim of these surveys will be to systematically test the associations between symptoms of the sick building syndrome, self-reports of work stress, passive smoking, ability to cope with stress, and other health and lifestyle factors in greater detail than that used in previous

studies. The survey will also measure indoor air quality in these buildings. Associations between pollutant concentrations and symptoms will be tested, controlling for significant personal and psychosocial variables. This work will build on previous research on smoking policy, psychosocial factors, and the sick building syndrome (Hedge *et al.*, 1991a,b, 1992, 1993a,b).

METHOD

The survey method which will be used will be based on the protocol developed by Hedge *et al.* (1991b) and adapted as follows:

Survey buildings

Eight air-conditioned buildings with either variable air or constant air volume ventilation systems will be studied. All buildings will be occupied by organizations conducting typical office work. All buildings will be in the Eastern U.S.A. Four buildings will operate a policy of prohibiting smoking and 4 will operate a policy of spatially restricting smoking. Permission to study 2 restricted smoking buildings has already been obtained. Recruiting the remaining 6 buildings within the allotted time is feasible based on our previous experiences with commercial buildings. All organizations will receive the results of the surveys for their building(s), as well as a copy of the results for all buildings.

Indoor Air Quality Survey

Environmental conditions in each building will be sampled in the winter/spring season over a consecutive two workday period. On each day two sites will be sampled in the morning and two more in the afternoon giving a total of 8 sites per building. All sampling will be conducted during normal office hours and on full working days. Where possible, sample sites will be chosen in the most densely occupied office areas with the least amount of full height walls/obstructions. Care will be taken to avoid the following: exterior walls and corners; areas receiving direct sunlight; palpable drafts; direct influences of supply or return ducts; mounting heights below 3 feet or above 5 feet; high traffic locations; and direct impacts from possible contaminant sources such as a photocopier. The following pollutants will be measured:

Carbon monoxide (CO) - CO can be a tracer of ETS, although it is not specific to ETS. CO can indicate the ingress of vehicle exhaust fumes from nearby streets or basement garages. CO will be measured with a portable electrochemical monitor with a detection range from 0-50 ppm ± 1% full scale accuracy. This will be zeroed as required on each sampling day and calibrated morning, early afternoon and at the end of the day with a certified span gas of 30 ppm CO in air.

Carbon dioxide (CO_2) - CO_2 is often used as an estimate of ventilation rate. Levels will be

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measured with a portable nondispersive infrared absorption gas analyzer with a measurement range of 50-9950 ppm (±0.01%, 50 ppm detection limit). The monitor will be calibrated using 99.99% dry nitrogen as a zero gas and a span gas of 1000 ppm CO_2 in nitrogen in the morning, early afternoon and at the end of the day.

Formaldehyde - will be measured using a portable, direct reading instrument (Interscan 1160SP). The detection element is an electrochemical voltametric sensor with a dual measurement range of 0 - 0.05 ppm and 0 - 2.0 ppm (0.005 ppm detection limit) The sensor requires annual factory calibration. Prior to each field measurement the unit will be checked and zeroed.

Nicotine - Nicotine is a tobacco specific compound and it will not measured in the smoking prohibited buildings. Nicotine will be measured by pumping air at 1 L min^{-1} for 6 hours through sorbent tubes containing XAD-4 resin contained in flame sealed glass tube sampling tubes with 2 sections of 20/40 mesh XAD-4 resin separated by a glass wool spacer. The front section contains 80 mg and the back up portion contains 40 mg of resin, and this samples gaseous and particulate phase nicotine at concentrations typically found in indoor environments (Eatough *et al.*, 1988). After sampling, the tubes will be capped, refrigerated, and sent to an analytical laboratory where the XAD-4 resin will be removed and the nicotine desorbed with ethyl acetate containing 0.01% triethylamine. An aliquot of the desorbed sample is injected into a gas chromatograph equipped with a thermionic specific (nitrogen/phosphorous) detector. The area of the resulting nicotine peak is divided by the area of the internal standard peak and compared with the area ratios from the injection of standards. The detection limit of this method is 0.56 $\mu g/m^3$ for a 360 liter sample.

Respirable suspended particulates (RSP) - A piezoelectric microbalance (3.5 µm impactor) will be used to measure RSP (the instrument will be factory calibrated with dilute welding fumes with a sensitivity of 180 mg/hz). The measurement range of the instrument is 0.01-3.5 mg/m^3. The sensor will be cleaned every 4 measurements, and the impactor and precipitator needle cleaned prior to sampling in each building. Air is sampled for 120 seconds (10 $\mu g/m^3$ detection limit).

Airborne particulates - Airborne particles in size fractions (0.3 µm, 0.5µm, 1 µm, and 5 µm) will be counted simultaneously over a 120 second period using a laser particle counter (Atcor 1000). The instrument requires annual factory calibration.

Illumination - Horizontal illumination will be measured with a digital illuminance meter with a measurement range of 0.01 to 99,900 lux ± 2%. Areas adjacent to windows will be avoided because these may not representative of general office illumination levels.

Temperature and Relative Humidity (RH) - Temperature and RH will be measured with digital hygro-thermometers. For RH the measurement range is 10 to 95% RH, with 0.1% resolution and an accuracy of ±2%. For temperature the measurement range is 0.0 to 80.0° C with 0.1°C resolution and an accuracy to ±0.1° C.

Noise - Measures of office noise (dBA, Leq 8 hr.) will be taken using a Brüel and Kjaer digital sound-pressure level meter (model 2231) with readings taken across the audible spectrum using a 1/3 - 1/1 octave filter set. Infrasound readings will also be taken using a modular infrasound filter attached to the meter. The meter has a 70 dB dynamic range, a 73 dB pulse range, and a frequency range of 2Hz - 70kHz.

Statistical Design and Analysis of the Indoor Environment Data

With the exception of nicotine, the effects of smoking policy on the physical environment data will be tested using analysis of variance, with smoking policy as the whole unit treatment factor, and time-of-day (morning or afternoon samples) and smoking designation of an area as the subunit treatment factors. The building will be the experimental unit for smoking policy. The effect of smoking policy will be tested using the pooled variation in mean response among the buildings within each policy as the error term. The locations at which the pollutant and environmental measures were taken within each building is the experimental unit for the time-of-day/smoking designation (nonsmoking/smoking) treatment combinations. Effects of time-of-day, smoking designation, interactions between these factors, and interactions of these factors with smoking policy will be tested with the variation among locations in buildings as the error term. Analysis of the nicotine data will be performed for the smoking restricted buildings. Again the building will be the experimental unit, but in these analyses an additional treatment (smoking area designation) will be incorporated in the analysis of variance. All interactions will be tested at a liberal alpha level, $\alpha = 0.1$, whereas main effects and contrasts will be evaluated at $\alpha = 0.05$ (Snedecor and Cochran, 1980). Partial correlations among the environmental measures will be calculated to account for the variation in the measurements due to the design variables. The distribution of pollutant measures will be tested for normality, and data appropriately transformed. Statistical analyses of the physical environment data will be performed using SAS (v.5.18).

Questionnaire Design

The core of the self-report questionnaire to be used is that developed in previous research on SBS (Hedge *et al.*, 1991a,b). This anonymous, self-administered questionnaire will ask about worker perceptions of ambient conditions, occupational factors, work-related SBS symptoms, and personal information. A smoking information section, which will vary according to the organization's smoking policy, will ask for detailed information about smoking history, smoking activity, exposure of nonsmokers to ETS, and attitudes towards ETS exposure. Answers to the ambient environment questions and the SBS symptom questions are made on a frequency of experience scale for the previous one month period in the building (never; 1-3 times/month; 1-3

times/week; every day). For each of these questions, workers are also asked whether or not they were experiencing this item at the time of completion of the questionnaire and these responses are used in analyses linking physical conditions to perceived conditions and symptoms. An example of the kind of questionnaire which will be used for these core questions is appended (Appendix 2).

Measures of Personal Disposition

The effects of personal disposition on symptom reporting will be assessed by including a scale which measures individual differences in negative affect. Negative affect (NA) is a general dimension of subjective distress that is an affective state characteristic of certain individuals (Watson *et al.*, 1988), and this is positively related to self-reports of stress (Watson and Pennebaker, 1989). NA is also strongly predictive of health complaints (Watson, 1988; Watson and Pennebaker, 1989). For example, NA as measured by the 10 item mood scale (e.g., distressed, upset) from the Positive and Negative Affect Schedule (PANAS), is significantly correlated with the Hopkins Symptoms Checklist (Watson *et al.*, 1988), which is a well developed instrument of general dysfunction. Respondents will be instructed to indicate the extent they have felt this way (not at all, very slightly through to extremely) over the prior week. The NA scale of the PANAS is extremely reliable over time as well as internally consistent (Watson *et al.*, 1988), and it has strong construct validity (e.g., convergent and discriminant validation). As indicated it is predictive of general symptom reporting, and therefore may be expected to be predictive of SBS symptom reporting. The inclusion of a measure of negative affect is important because one potential explanation for the correlations between job stress and SBS which have been reported is that these are attributable to a spurious third variable related to personal attitudes or beliefs, such as negative affect.

Measures of Coping with Stress

Individual differences in coping style when faced with similar external stressors will be assessed using the Cybernetic Coping Scale (CCS). This scale has been developed from Edward's cybernetic theory of stress, coping, and well-being (Edwards, 1992) which conceptualizes stress as any discrepancy between an individual's desired state and their perceived state which is considered important by that person. Five forms of coping behaviors which attempt to eliminate or at least reduce negative discrepancies that adversely affect health and well-being can be distinguished: attempts to adjust the situation to match the desire; attempts to adjust desires to match the situation (accommodation); attempts to reduce the perceived importance of the discrepancy (devaluation); attempts to directly improve well-being (symptom reduction); and re-directing attention away from the situation (avoidance). In this theory, stress and coping are critical parts of a negative feedback loop whereby stress damages well-being, which in turn activates coping, which in turn reduces stress and improves well-being either directly as a consequence of

stress-reduction, or indirectly improves well-being as a consequence of one or more of the five coping strategies. Recent work testing the construct validity of the CCS, and other self-report measures of coping with stress, shows that the CCS is the most valid self-report measure, and a short-version of this (20 item CCS) is sufficient to provide both a parsimonious and valid representation of the five categories of coping proposed by cybernetic theory (Edwards and Baglioni, 1993).

Measures of Occupational Factors and Stress

Jobs will be categorized as managerial, professional, technical, and clerical or secretarial, and if necessary additional categories will be developed. Hours of computer use will be assessed. Previously, perceived work stress has been measured using a 5 item job stress measure and a 5 point rating scale (strongly agree; mostly agree; uncertain; mostly disagree; strongly disagree). To further investigate the sources of perceived work stress, this scale will be expanded by including a number of questions about work content, control, variety and demands. Additional stress scales will also be added. These include scales of job demands, job control (Karasek, 1979, Karasek and Theorell, 1981) and social support (Caplan *et al.*, 1975; House, 1981). The former have been used extensively and are predictive of both physical and psychological health symptoms. Specifically, the combination of high demands and low control have been shown to predict ill health both in cross-sectional and prospective designs (Karasek and Theorell, 1990; Evans *et al.*, in press). Social support at work also has direct and buffering effects with job stressors on health and well being (Evans *et al.*, in press; House, 1981; House and Kahn, 1985). Furthermore, the combination of high demands, low control, and low support appears to further increase risk above either two-way combination (Johnson and Hall, 1988). Stress will also be measured by the Perceived Stress Scale (PSS), which is a 14 item scale which is readily understood by office workers. This scale will ask respondents to indicate symptoms of stress at work for the previous week. The PSS is a highly reliable and valid self-report instrument for assessing experienced stress over short or long-term periods. Normative data for working adults is also available for the PSS. The PSS is predictive of negative health outcomes consistent with stress and coping theory (Cohen *et al.*, 1983). Job satisfaction will be measured using a refined set of 6 items adapted from a short "Job Satisfaction Scale" (Brayfield and Rothe, 1951) which are answered on a five point rating scale (strongly agree; mostly agree; uncertain; mostly disagree; strongly disagree).

Measures of Health and Other Lifestyle variables

Previous work has reported a beneficial effect of coffee consumption on mucosal irritation symptoms (Skov *et al.*, 1987, 1989), and questions on daily consumption of various beverages (caffeinated and decaffeinated coffee, tea, fruit juices, sodas, etc.) will be included in the questionnaire. The Danish Town Hall study did not find a significant effect of regular exercise

on SBS symptoms (Skov et *al.*, 1989). However, they only asked about regular exercise using a single, yes/no question. Research shows that stress can change immune function. Significant correlations between environmental stress factors, perceived health complaints and levels of immunoglobulin and complement components among aviators have been reported. In a multiple regression analysis, perceived work stress explained 31% of the variance in complement component (C3) and psychological defense and complaints related to immune status explained 15% of the immunoglobulin-A variance (Vaernes *et al.*, 1991). Regular, moderate exercise may help to reduce the negative effects of stress, while regular vigorous exercise may itself be stressful to the body. Questions will be included in the questionnaire to test whether workers who regularly exercise before, at, or after work to help alleviate work stress report fewer SBS symptoms than those who do not do this. SBS reports are associated with other lifestyle variables, such as conflicts between work and domestic demands and organization of child care difficulties for single parents (Wallace *et al.*, 1991). Other variables, such as worries about elder care, may show similar associations. Questions on these topics will be included in the survey questionnaire.

Questionnaire Survey

While the indoor climate survey is being conducted, questionnaires will be distributed to clusters of approximately 30 workers seated in the immediate vicinity of the air quality sample site. This will yield a sample of around 240 workers per building, and therefore a total survey size of about 1,920 workers. Questionnaires will be distributed and collected by the researchers on the same day. Workers unable to complete the questionnaire on the same day will be given a pre-addressed return envelope. Upon collection of questionnaires respondents will be asked whether or not they would be willing to participate in Phase 2 of this research. The name, address, and phone number of those who may be willing to participate in Phase 2 will be logged on a master list against their questionnaire ID number.

Statistical Design and Analysis of the Questionnaire Data

The general analytical strategy which will be followed previously has been described in detail (Hedge *et al.* 1991, 1992, 1993b). In brief, descriptive statistics, logistic regression and multiple regression analyses will be performed in SAS (v.5.18). All data will initially be screened for normality and where assumptions of normality are violated the data will be transformed appropriately. Separate logistic regression models will be run to test the relationships of each of the environmental measures with each of the perceived environmental conditions and each of the SBS symptoms. Each model will allow every building to have its own intercept but a common slope with respect to the environmental measure which is the dependent variable. Each analysis will

assess how, for each of the environmental measures, the odds of reporting the experience of each of the environmental conditions and each of the SBS symptoms are affected. To test for associations between the psychosocial variables and the SBS, multiple regression analysis will be used to model the relationships between personal, occupational and psychosocial variables, and the total number of SBS symptoms reported by workers. Analysis of variance will be used to test for effects of smoking policy on environmental conditions in the smoking prohibited and smoking restricted buildings, and, as appropriate, these analyses will include adjustments for the smoking designation of test areas (in the restricted smoking buildings), the day (first or second) and time of survey (morning or afternoon). Differences in the survey responses for the perceived environmental conditions and reports of SBS symptoms between workers in these two smoking policies will be tested using Cochran Mantel-Haenzel Chi-Square tests which will include the building as an adjustment factor. Other statistical analyses will be conducted as required.

PHASE 1 CASE-CONTROL PRELIMINARY STUDY

Concurrent with the cross-sectional surveys, a preliminary study of biomarkers of work stress (urinary cortisol and catecholamines) and passive smoking (urinary cotinine) will be conducted in preparation for the Phase 2 longitudinal case-control study.

METHOD

Subjects - Ten female workers, 5 smokers and 5 nonsmokers, from a Cornell office building will participate in a pilot study designed to fine tune procedures for data collection and measurement for Phase 2 of the current project. These workers will be recruited from a University building, but not necessarily a known problem building. Each subject will be paid $50 for their participation, since extensive contact will be maintained throughout the pilot phase, including completion of self-report questionnaires and a lengthy interview.

Procedure

On one day of study per subject, environmental conditions will be monitored at the subject's workstation using the instrumentation described for the cross-sectional survey. Where possible, conditions will be sampled throughout each subject's workday. Each subject will complete the self-administered questionnaire developed for the cross-sectional survey and will keep a diary record of environment conditions, SBS symptoms, and work stress (see phase 2 method for further details). In the course of a workday for each subject an eight hour work-day urine sample will be collected. Each subject will be told about the purpose of the study, they will be told exactly what substances

will be tested for in their urine, and they will be assured that tests for recreational substances will not be conducted and that no individual results will be seen by anyone other than Cornell researchers. Each subject will be given a specimen bottle and instructed to void all urine throughout the work day into the bottle. A preservative (metabisulfite) is placed in the bottle. The bottle is collected at the end of the work day, the volume measured, and samples extracted for biomarkers of stress and ETS exposure. Each subject will also collect an eight hour urine sample at home during a nonwork day which will serve as a baseline measure. The co-principal investigator has employed this measurement procedure successfully in several studies (cf., Evans et al, in press).

Biomarkers of chronic stress - Four, 5 ml urine samples are randomly extracted from each daily volume of urine. Two samples are pH adjusted. All four samples are deep frozen (-70°C). The pH adjusted samples will be analyzed for adrenaline (epinephrine) and noradrenaline (nor epinephrine) by high performance liquid chromatography using a reverse phase with electrochemical detection (Riggin and Kissinger, 1977). Cortisol will be measured with a radioimmune assay (Baxter Travelog Diagnostics, 1987). Urine will also be collected for an eight hour period at home on a non-work day in order to obtain baseline measures.

Urinary indexes of neuroendocrine functioning have been widely used in the U.S.A. (Baum *et al.*, 1982; Grunberg and Singer, 1990) and in Scandinavia (Lundberg, 1984) as markers of chronic stress. Catecholamines and cortisol are reliably elevated when psychological stress is increased, either experimentally or by natural conditions. The catecholamines, particularly adrenaline, but not cortisol, are elevated when environmental demands are present. Cortisol seems most sensitive to distress (Frankenhauser, 1986). Very high intra-individual stability has also been noted in urinary measures (Forsman and Lundberg, 1985). Plasma measures of neuroendocrine functioning are not preferable when indexes of chronic stress are desired because they are unstable, mirroring moment to moment changes, and therefore they are not suitable for time averaged indexes. Urinary measures are preferable to plasma indexes when chronic stress measures are desired (Grunberg and Singer, 1990; Lundberg, 1984, 1985).

Biomarkers of ETS exposure - Cotinine is the major metabolite of nicotine and it has been shown to be a good indicator of ETS exposure (Matsukura *et al.*, 1979). Urinary cotinine shows a dose-response relationship with the number of cigarettes smoked (Hoffman *et al.*, 1983; Matsukura *et al.*, 1984). Cotinine in urine has been used as a measure of ETS exposure both in adult nonsmokers (Lewis *et al.*, 1990) and in children (Collier *et al.*, 1990). The half-life of cotinine in urine is between 7 and 40 hours, tending to be longer in never smokers, and the amount of inhaled nicotine excreted as cotinine averages 11% (Lewis *et al.*, 1990). Eight hours of urine will be collected over the workday and for one day at home. Two, 5 ml urine samples will be randomly drawn and deep frozen from each 8-hour pool. Urinary cotinine will be measured by a

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radioimmunoassay such as DPC nicotine metabolite double antibody kit. A chloroform extraction is performed after thawing. (Langone *et al.*, 1973).

Subject Interviews - At the end of the pilot study subjects will be informally interviewed in depth by the researchers to gain additional insights into the methodology and measures used.

Statistical analyses - Associations between self-report measures of SBS symptoms, stress, and ETS exposure, either from active or passive smoking, coping ability and other personal and lifestyle variables will be tested using logistic and multiple regression methods. However, because of the small sample size further extensive statistical analyses will not be undertaken at this stage.

PHASE 2: LONGITUDINAL CASE-CONTROL STUDY OF SBS

Phase 2 Aim: Conduct a longitudinal case-control study of SBS symptomatic and asymptomatic workers in smoking prohibited and spatially restricted smoking buildings to investigate associations between self-reports of work stress, passive smoking, psychosocial variables and urinary biomarkers of stress and ETS exposure, and seasonal variations in these and in the SBS.

As already described, many studies have established that stress and possibly passive smoking play an important role in the etiology of the sick building syndrome. The role of stress and passive smoking will be further investigated by combining subjective assessments of health, disposition, and the psychosocial characteristics of the job environment, with physiological measures of stress and ETS exposure.

METHOD

Subjects

One hundred subjects will be recruited from two of the buildings, one nonsmoking and one with restricted smoking, surveyed in Phase 1. Fifty subjects will have reported no SBS symptoms (controls), and 50 will have reported 3 or more SBS symptoms (cases). If possible within each building subject selection for each of these case/control groups will be matched for gender in approximately the same proportions. Within each building, preference will be given to selecting subjects who are on the same office floor of the building so that environmental conditions can be monitored for the office area at the same time as subjective and biological measures are being taken. Each subject will be paid $50 per measurement wave. Based on our previous research experience, a 20% attrition rate is anticipated over the four quarters, yielding an N=80.

Procedure

Each subject will keep a diary card to record their experiences for a full work week (Monday through Friday). This diary card will record their perceived environmental conditions and symptoms (for an example of the kind of diary card which will be developed see Appendix 3). The diary card will be modified to include assessments of job stress. In the course of the last workday for each subject an eight hour work-day urine sample will be collected. Each subject will be told about the purpose of the study, they will be told exactly what substances will be tested for in their urine (catecholamines, cortisol, and cotinine), and they will be assured that tests for recreational substances will not be conducted and that no individual results will be seen by anyone other than Cornell researchers. On that day the environmental conditions in the subjects' office area will be monitored using the instrumentation and the protocol described for Phase 1. The Phase 1 procedure for collecting urine and monitoring conditions, with any modifications indicated by the pilot study, will be used. At the end of the last workday each subject will also complete the self-administered questionnaire developed for the cross-sectional survey. Previous work has shown a significant, although weak correlation between seasonal affective disorder and the SBS. For the present study the questionnaire will be modified to include questions on SAD which will allow assessment of seasonal variations in SAD scores and test their association with the SBS. On one day of the following weekend each subject will also void an eight hour urine sample approximately 8:00 - 17:00) to serve as a baseline measure. Testing of each subject will occur once during each season: spring, summer, fall, and winter. Four waves of data collection will enable us to track changes in perceived job stress, negative affect, SBS, and environmental conditions.

Data analysis

Data will be checked, verified, tested for normality, and transformed as required. The analyses will focus on testing several research questions, for example: is the association between self-reported job stress and SBS symptoms reflected by urinary measures of stress; do self-reports of stress and passive smoking correlate with their corresponding biomarkers; does negative affect mediate or moderate the predicted associations between perceived and physiological stress and SBS symptoms; are there differences in cotinine between smokers and never smokers in a smoking prohibited and a restricted smoking building; is there an association between urinary cotinine and SBS symptoms; are there any associations between work environment conditions and SBS symptoms when negative affect, psychophysiological stress, and passive smoking are statistically adjusted; does the pattern of work environment experiences differ for SBS symptomatic and asymptomatic workers; do the diary measures show a temporal pattern in SBS symptoms; are there seasonal differences in the SBS?

The analyses will employ a variety of correlation methods and inferential tests as required. For example, logistic and hierarchical multiple regression methods will be used to test for associations between specific predictors (e.g. job stress) and criterion variables (e.g. SBS symptoms). These analyses will use models in which possible mediating variables are systematically included or excluded in tests of associations (Baron and Kenny, 1986; Evans and Lepore, in press). Since mediator status requires no interaction (analagous to one of the assumptions for covariance analysis), the possibility for moderator patterns will first be examined. As a simple illustration of the mediation testing approach, assume that the association between the PSS, urinary cortisol, and the number of SBS symptoms is being tested. For this we will let Y = the number of SBS symptoms, X_1 = the PSS score, and X_2 = urinary cortisol. The various regression models to be tested would be as follows:

(1) $Y = B_0 + B_1X_1 + e$ where e = error, B_0 = intercept

(2) $Y = B_0 + B_2X_2 + e$

(3) $Y = B_0 + B_2X_2 + B_1X_1 + e$

Assuming that equations (1) and (2) are significant (i.e. there appear to be associations between the PSS and the SBS and between cortisol and the SBS) then if the previously significant B_1 in equation (1) becomes nonsignificant for equation (3), cortisol (B_2) is a significant mediator and this may be the route by which stress and the SBS are linked. Furthermore, reversal of the X_1 and X_2 terms allows us to examine spuriousness. In the absence of spuriousness, partialling of X_1, should <u>not</u> alter the estimate of B_2. See Evans and Lepore (in press) for more details. Also as noted above, prior to the mediation test, we will examine the potential interactive effect of the predictor (X_1) and the hypothesised mediator (X_2). Lack of interaction is a pre-requisite for the mediational analysis shown in equations 1-3. Moreover, given the longitudinal design, we can examine residualized SBS symptoms, i.e. changes in SBS reports. Thus another advantage of the longitudinal design is stronger internal validity given that the temporal precedence of variables is known. Use of change scores in symptoms also dramatically improves our ability to eliminate self-selection counter hypotheses.

SIGNIFICANCE OF THE PROPOSED WORK

This research will clarify many issues concerning the etiology of the SBS. The cross-sectional surveys will determine the effects of mostly untested psychosocial and lifestyle variables (negative affect, coping abilities, job control, social support, perceived stress, exercise, beverages, etc.) on reports of the SBS among workers in smoking prohibited and restricted smoking buildings. Previous research on alternative smoking policies (Hedge *et al.*, 1991b, 1993b) has found that

SBS symptoms are slightly more prevalent among workers in smoking prohibited buildings and this research will also test whether this can be confirmed in a separate study. The effects of smoking restriction on indoor air quality will be evaluated and results compared with previous findings (Hedge *et al.*, 1991b, 1993b). The effects of indoor air pollutants on the relative risk of reporting SBS symptoms when psychosocial variables have been statistically adjusted will be tested.

The case-control study will determine the effects of work stress and passive smoking on reports of the SBS by investigating both physiological and self-report measures of these variables. It will show whether changes in urinary biomarkers of stress and passive smoking correlate with reports of SBS symptoms; and if either or both of these do, it will demonstrate whether they function as moderators or mediators of SBS symptoms. The research will also determine whether or not there are seasonal variations in the SBS, which may explain the association of symptoms with seasonal affective disorder, and whether these correspond with changes in urinary biomarkers and self-report measures of passive smoking and stress. The use of diary records will allow the temporal pattern of symptoms among SBS sufferers and possible precipitating settings or conditions to be investigated. The research will elucidate the extent to which urinary biomarkers correlate with self-reports of work stress and passive smoking, thereby testing the validity of using these self-report assessments in SBS research. Furthermore, our multimethodological approach in combination with both cross-sectional and longitudinal designs will afford a substantially stronger research design than achieved in prior research on the SBS.

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Available Facilities and Resources

DEA is housed in the East Wing of the College of Human Ecology's building, occupying over 20,000 square feet of office, laboratory, and support space. DEA has a metal/wood workshop, its own computing lab, and a xerox/fax and graphic's production space. DEA employs a full time administrative manager and a full time bookkeeper in addition to secretarial staff. Extensive mainframe computer support and research library facilities are available to all faculty at Cornell.

Portable Environmental Monitoring Equipment

The following portable instrumentation will be provided by the researchers for use in this project:

Carbon monoxide monitor	Interscan (CO) and Ecolyzer (2000) electrochemical monitors with a detection range from 0-50 ppm ± 1% full scale accuracy.
Carbon dioxide monitor	Riken 411 nondispersive infrared absorption gas analyzer with a measurement range of 50-9950 ppm(± 0.01%, 50 ppm detection limit).
Formaldehyde monitor	Interscan 1160SP portable, direct reading instrument with a dual measurement range of 0 - 0.05 ppm and 0 - 2.0 ppm (0.005 ppm detection limit).
Particulate monitors	A TSP piezoelectric microbalance (3.5 µm impactor) with a measurement range of t0.01-3.5 mg/m^3 and a 10 $\mu g/m^3$ detection limit (120 second sample). A laser particle counter (Atcor 1000) simultaneously counts airborne particles in size fractions (0.3 µm, 0.5 µm, 1 µm, and 5 µm).
Illumination	A digital illuminance meter (Minolta) with a measurement range of 0.01 to 99,900 lux ± 2%.
Temperature and RH	Two digital hygro-thermometers (Brooklyn thermometer company). For RH the measurement range is 10 to 95% ± 2%. For temperature the measurement range is 0.0 to 80.0° C ±0.1° C.

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Noise	A Brüel and Kjaer digital sound-pressure level meter (model 2231) and a 1/3 - 1/1 octave filter set. The meter has a 70 dB dynamic range, a 73 dB pulse range, and a frequency range of 2Hz - 70kHz.
Air Sample Pumps	SKC model 224 (10 pumps)
Gilibrator Pump Calibrator	Model 800271
Computer equipment	Various equipment, but some of this is in need of upgrading or replacement

Total Equipment Value		Initial Purchase Costs
10 X	SKC Personal Air Sampling Pumps	8,124
1 X	Gillian Pump Calibrator	895
1 X	Ecolyzer 2000 CO Monitor	2,100
1 X	Interscan CO Monitor	1,700
1 X	Riken 411 CO_2 Monitor	2,650
1 X	Minolta Chroma Meter	1,386
1 X	Brüel & Kjaer Type 2231 Sound Pressure Level Meter, 1/1-1/3 Octave band filter	10,546
2 X	Macintosh SE w/20 Mb HD	4,300
2 X	Macintosh LaserWriter IINT	6,504
1 X	Toshiba 1600 portable	2,700
1 X	Macintosh IIcx 40Mb 5M RAM Computer and Color Monitor	6,815

Total costs of equipment available for use in this project $47,720

Biochemical Laboratory

Biochemical assays of urinary cortisol, catecholamines, and cotinine will be conducted in Evans' biochemical assay laboratory at Cornell. Evans spent a year's fellowship in Frankenhaeuser and Lundberg's laboratory at the Karolinska Medical School learning neuroendocrinological assay techniques. The laboratory is staffed by a technician who has a BS in chemistry and is highly experienced in biochemical assays of neuroendocrine secretions related to stress. She is also familiar with the RIA for cotinine.

The facility is a fully equipped biochemical assay laboratory (e.g., HPLC, Gamma counter, refrigerated centrifuge).

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Other Support: Alan Hedge

The Effects of Smoking Policy and Building Ventilation on Indoor Air Quality and Employee Comfort and Health in Offices. Current, CIAR. $ 78,052. 1/93 - 12/93. 15% effort. The present proposal builds upon and extends this earlier work. Cross sectional surveys are investigating the effects of indoor air pollutents and indoor climatic conditions on perceived environmental conditions and SBS symptoms among office workers in buildings operating different smoking policies.

Other Support: Gary W. Evans

The Adaptive Costs of Coping with Multiple Stressors
Pending, NSF. $ 348,733. 1/94 - 12/96 10% effort. No overlap with present proposal. Lab and field studies to examine whether multiple, sequential stressors have multiplicative or additive effects.

Physiological Analyses of Human Environment Relations
Pending, NSF (Instrumentation and Laboratory Improvement). $ 19,892. 5/93 - 11/95 N/A effort. No overlap with present proposal. Equipment grant to improve teaching laboratory facilities.

Chronic Stress as a Risk Factor in the Etiology of Coronary Heart Disease
Current, NHLBI, Swedish Environmental Protection Board, Nordic Noise Council. $ 306,998. 9/90 - 8/95 10% effort. No overlap with present proposal. Longitudinal study of the effects of airport noise on children's psychophysiological, cognitive, and quality of life outcomes.

Traffic Congestion and the Work Environment of City Bus Drivers
Current, NSF, Swedish Work Environment Fund, Swedish Transport Research Board. $ 196,000. 12/89 - 11/93. 5% effort. No overlap with present proposal. Physiological stress and work environment of urban bus drivers.

——SEE ATTACHED BREAKDOWN OF BUDGET BY PERIOD——

12.BUDGET: Detailed specific needs for the first 12-month period. Estimate category sub-totals for 2nd and 3rd periods, if required. Append justifications.

(a) Salaries. List personnel by name and title. Indicate individuals % time to be spent on this project.	$ 1st period	$ 2nd period	$ 3rd period
% Professional:			
Hedge	12,754	13,392	14,062
Evans	3,413	7,166	7,525
% Technical:			
RSS III	28,000	29,400	30,870
Fieldwork Asst.	4,000	2,640	960
Lab Tech	5,565	11,743	12,389
% Other:			
Secretarial	4,000	4,400	4,840
Grad Asst.	3,000	3,300	3,600
Fringe benefits payable at institution's rate of %	21,234	25,283	25,984
Category (a) Sub-Total	81,966	97,324	100,230
(b) Consultants (per diem, travel & expenses): G. Rubin	5,200	5,600	6,000
Category (b) Sub-Total	5,200	5,600	6,000
(c) Supplies & Expense: Consumables (by category)	11,470	10,530	10,154
Animals and related costs	---	---	---
Other expenses (itemize)	7,706	24,452	13,074
Category (c) Sub-Total	19,176	34,982	23,228
(d) Travel Expenses:	12,200	8,680	4,740
Category (d) Sub-Total	12,200	8,680	4,740
(e) Alterations and Renovations	---	---	---
Category (e) Sub-Total			
(f) Sub-contracts	---	---	---
Category (f) Sub-Total			
(g) Equipment	7,801	3,150	3,150
Category (g) Sub-Total	7,801	3,150	3,150
(h) TOTAL DIRECT COSTS	126,343	149,736	137,348
(i) Indirect costs not to exceed 25% of the sum of (a) thru (f):	29,636	36,647	33,550
(j) TOTAL PROJECT COSTS	155,979	186,383	170,898

THE EFFECTS OF WORK STRESS, PASSIVE SMOKING, NEGATIVE AFFECT, COPING ABILITY, AND OTHER LIFESTYLE FACTORS ON THE SICK BUILDING SYNDROME.

Year 1 - 1994 Items	1994 Costs	
(a) Salaries		
Professional:		
Prof. A. Hedge, 20%	12,754	
Prof. G. Evans, 5%	3,413	
Technical:		
Research Support Spec III	28,000	
Temp. Fieldwork Assistant (40 days@$100/day)	4,000	
Laboratory Technician (25%)	5,565	
Other:		
Part-time Secretarial Assistance	4,000	
Part-time Grad Assistants (300 hrs@$10/hr)	3,000	
Fringe Benefits @36.78% on $57,732 (grad asst. excl.)	21,234	
Category (a) Sub-total:		**$81,966**
(b) Consultants		
Statistical Consulting - Dr. G. Rubin (80 hrs@$65/hr)	5,200	
Category (b) Sub-total		**$5,200**
(c) Supplies & Services:		
Photocopying	620	
Questionnaire, printing (2000)	4,000	
Telecommunications (phone/fax)	2,200	
Office supplies/sundries	1,650	
Contingency	3,000	
	11,470	
Other expenses		
Equipment Calibration		
-Piezobalance calibration	1,000	
-Formaldehyde sensor	100	
-Particle counter	250	
-Calibration gases	250	
Commercial Laboratory Analyses of Nicotine		
-4 bldgs. x 8 samples + 4 blanks @$45	1,620	

Biochemical Assays		
-RIA Kits (Cortisol	80	
-RIA Kits (Cotinine)	200	
-Chemicals & Reagents	1,500	
-Glassware	240	
-Plasticware	120	
-HPLC Parts	500	
-Radioactive Waste Disposal	250	
-Maintenance Contract	1,096	
	7,706	
Category (c) Sub-total:		**19,176**
(d) Travel Expenses		
8 bldgs. (5 days/bldg. x 2 people @$125/pp)	10,000	
2 Conference presentations	2,200	
Category (d) Sub-total		**$12,100**
(g) Equipment		
Infrasound Filter (B&K Type 1627)	2,075	
Computer equipment - to be specified (>$500)	3,100	
Portable Ultra Low Freezer (VWR 140-5)	2,626	
Category (g) Sub-total:		**$7,801**
(h) TOTAL DIRECT COSTS:		**$126,343**
(i) INDIRECT COSTS @25% on $118,542		**29,636**
(j) YEAR 1 TOTAL COSTS:		**$155,979**

Alan Hedge

THE EFFECTS OF WORK STRESS, PASSIVE SMOKING, NEGATIVE AFFECT, COPING ABILITY AND OTHER LIFESTYLE FACTORS ON THE SICK BLDG. SYNDROME

Year 2 - 1995 Items	1995 Costs	
(a) Salaries		
Professional:		
Prof. A.Hedge, 20%	13,392	
Prof. G. Evans,10%	7,166	
Technical:		
Research Support Spec III	29,400	
Temp Fieldwork Assistant (24 days @$110/day)	2,640	
Laboratory Technician (50%)	11,743	
Other:		
Part-time Secretarial Assistance	4,400	
Part-time Grad Assistants (300 hrs @$11/hr)	3,300	
Fringe Benefits @36.78% on $68,741 (grad asst. excluded)	25,283	
Category (a) Sub-total		**$97,324**
(b) Consultants		
Statistical Consulting - Dr. G. Rubin (80 /hrs@$70)	5,600	
Category (b) Sub-total		**$5,600**
(c) Supplies & Services:		
Photocopying	850	
Questionnaire, diary printing	1,000	
Telecommunications (phone/fax)	3,480	
Office supplies/sundries	1,900	
Contingency	3,300	
	10,530	
Other expenses		
Equipment Calibration		
-Piezobalance calibration	1,000	
-Formaldehyde sensor	100	
-Particle counter	250	
-Calibration gases	250	

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Alan Hedge

Commercial Laboratory Analyses of Nicotine		
-(2 bldgs. x 8 samples x 3 seasons + 6 blanks @$50)	2,700	
Biochemical Assays		
-RIA Kits (Cortisol)	600	
-RIA Kits (Cotinine)	1,600	
-Chemicals & Reagents	750	
-Glassware	800	
-Plasticware	600	
-HPLC Parts	750	
-Radioactive Waste Disposal	750	
-Maintenance Contract	2,302	
Subject Payment (3 x 80 x $50)	12,000	
	24,452	
Category (c) Sub-total:		34,982
(d) Travel Expenses		
2 Bldgs. x 3 seasons (4 days/bldg. x 2 people @$135/pp)	6,480	
Conference presentations	2,200	
Category (d) Sub-total		8,680
(g) Equipment		
Computer equipment - to be specified (>$500)	3,150	
Category (g) Sub-total		3,150
(h) TOTAL DIRECT COSTS:		149,736
(i) Indirect Costs @25% on $146,586		36,647
(j) YEAR 2 TOTAL COSTS		$186,383

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Alan Hedge

THE EFFECTS OF WORK STRESS, PASSIVE SMOKING, NEGATIVE AFFECT, COPING ABILITY AND OTHER LIFESTYLE FACTORS ON THE SICK BUILDING SYNDROME.

Year 3 - 1996 Items	1996 Costs	
(a) Salaries		
Professional:		
Prof. A. Hedge, 20%	14,062	
Prof G. Evans, 10%	7,525	
Technical:		
Research Support spec III	30,870	
Temp. Fieldwork Assistant (8 days @$120/day)	960	
Laboratory Technician (50%)	12,389	
Other:		
Part-time Secretarial Assistance	4,840	
Part-time Grad Assistants (300 hrs@$12/hr)	3,600	
Fringe Benefits @36.78% on $70,646 (grad asst. excl.)	25,984	
Category (a) Sub-total		**$100,230**
(b) Consultants		
Statistical Consulting - Dr. G. Rubin (80 hrs@$75/hr)	6,000	
Category (b) Sub-total:		**$6,000**
(c) Supplies & Services:		
Photocopying	780	
Questionnaire, diary, final report printing	500	
Telecommunicaitons (phone/fax)	3,174	
Office supplies, sundries	2,100	
Contingency	3,600	
	10,154	
Other expenses		
Equipment Calibration		
-Piezobalance calibration	1,000	
-Formaldehyde sensor	100	
-Particle counter	250	
-Calibration gases	250	
Commercial Laboratory Analyses of Nicotine		
-4 bldgs. x 8 samples + 4 blanks @$45	990	

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Alan Hedge

Biochemical Assays		
-RIA Kits (Cortisol)	200	
-RIA Kits (Cotinine)	400	
-Chemicals & Reagents	600	
-Glassware	500	
-Plasticware	600	
-HPLC Parts	750	
-Radioactive Waste Disposal	900	
-Maintenance Contract	2,534	
Subject Payment (80 x $50)	4,000	
	13,074	
Category (c) Sub-total:		**$23,228**
(d) Travel & Expenses		
2 Bldgs. 4 days/bldg. x 2 people @$145/pp)	2,320	
2 Conference presentations	2,420	
Category (d) Sub-total		**$4,740**
(g) Equipment		
Computer equipment - to be specified (>$500)	3,150	
Category (g) Sub-total		**$3,150**
(h) TOTAL DIRECT COSTS		**$137,348**
(i) INDIRECT COSTS @25% on $134,198	**33,550**	
(j) YEAR 3 TOTAL COSTS		**$170,898**

APPENDIX 1

Timetable for the Research Project

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Project Schedule

Quarter	1994	1995	1996
Jan. - March	Selection of building sample Finalize survey questionnaire Survey 2 restricted smoking buildings which have already agreed to participate		
April - June	Survey 3 smoking prohibited buildings Survey 1 restricted smoking building		
July - Sept.	Data entry & verification Descriptive statistics Organize surveys of final 2 buildings Begin biomarker pilot project		
Oct. - Dec.	Survey 1 smoking prohibited building Survey 1 restricted smoking building Data entry & verification Descriptive statistics Complete biomarker pilot project		
Jan. - March		Complete analysis of biomarker pilot project Select final sample for case-control groups Schedule building surveys and case-control study	
April - June		Case-control study - first quarter data collection Biomarker analysis Data entry and verification for biomarkers, questionnaires, and diaries	
July - Sept.		Case-control study - second quarter data collection Biomarker analysis Data entry and verification for biomarkers, questionnaires, and diaries	
Oct. - Dec.		Case-control study - third quarter data collection Biomarker analysis Data entry and verification for biomarkers, questionnaires, and diaries	
Jan. - March			Case-control study - fourth quarter data collection Biomarker analysis Data entry and verification for biomarkers, questionnaires, diaries
April - June			Data analyses: multivariate analyses of biomarker, questionnaire, diary data (regression analyses etc.)
July - Sept.			Preparation of conference papers, journal article(s)
Oct. - Dec.			Preparation of journal article(s) Preparation and submission of final report

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APPENDIX 2

Example of the core self-report questionnaire which will be modified and expanded to include the measures described in the proposal

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CORNELL OFFICE ENVIRONMENTAL QUALITY SURVEY

This survey is being conducted by researchers at Cornell University to determine the environmental quality of your office building. This questionnaire asks about how you think your office environment and your work affect you. Please answer the questions as accurately and completely as you can, regardless of how satisfied or dissatisfied you are with conditions in the office.

You do not need to put your name on the questionnaire, and all of your answers will be treated in the STRICTEST CONFIDENCE.

Answer directions: place a ◯ around the appropriate number to indicate your answer to each question.

Answer like this: 1 2 3 4 5

If you make a mistake: erase your incorrect answer then put a ◯ around the correct response

OFFICE USE ONLY						
#	Bldg.	Floor	Area	D	T	Case

General Information I

1. How long have you worked in this building?

Years								
less than 1	1	2	3	4	5	6	7	8 or more

2. How many days a week do you work in this building?

Days a week						
1	2	3	4	5	6	7

3. How many hours a day do you work in this building?

Hours a day								
less than 1	1	2	3	4	5	6	7	8 or more

4. How old are you?

Years					
19 or less	20-29	30-39	40-49	50-59	60 or more
1	2	3	4	5	6

5. What is your sex?

Female	Male
1	2

6. Please indicate any of the following you presently suffer from:

Migraine	Asthma	Eczema	Hayfever	Other Allergies	Chronic Backpain
1	2	3	4	5	6

7. What is your smoking status:

Non Smoker	Former Smoker	Current Smoker
1	2	3

8. What types of correction lenses do you usually wear?

None	Reading glasses	Regular glasses	Other glasses	Contact lenses
1	2	3	4	5

All answers are STRICTLY CONFIDENTIAL

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Environment

9. Please circle below the day of the week and the time of day you are completing this questionnaire:

• DAY OF THE WEEK

Monday	Tuesday	Wednesday	Thursday	Friday
1	2	3	4	5

• TIME OF DAY

AM	PM
1	2

10. During the PAST MONTH how often have you experienced each of the following environmental conditions while working in this building?					11. Overall, during the PAST MONTH how much has your work been disrupted by this condition?			12. What TIME OF DAY is this condition usually experienced?				13. Are you CURRENTLY experiencing this condition?	
Conditions	Never	1 to 3 times a Month	1 to 3 times a Week	Almost every day	Not at all disrupted	Somewhat disrupted	Very disrupted	AM	PM	Both	No Pattern	YES	NO
a. temperature too warm	1	2	3	4	1	2	3	1	2	3	4	1	2
b. temperature too cold	1	2	3	4	1	2	3	1	2	3	4	1	2
c. satisfactory temperature	1	2	3	4	1	2	3	1	2	3	4	1	2
d. satisfactory lighting	1	2	3	4	1	2	3	1	2	3	4	1	2
e. lighting too dim	1	2	3	4	1	2	3	1	2	3	4	1	2
f. glare problems from lighting	1	2	3	4	1	2	3	1	2	3	4	1	2
g. insufficient ventilation	1	2	3	4	1	2	3	1	2	3	4	1	2
h. uncomfortable drafts	1	2	3	4	1	2	3	1	2	3	4	1	2
i. too little air movement	1	2	3	4	1	2	3	1	2	3	4	1	2
j. air too dry	1	2	3	4	1	2	3	1	2	3	4	1	2
k. air too humid	1	2	3	4	1	2	3	1	2	3	4	1	2
l. distracting ambient noise	1	2	3	4	1	2	3	1	2	3	4	1	2
m unpleasant odor in air	1	2	3	4	1	2	3	1	2	3	4	1	2
n. "stale" air	1	2	3	4	1	2	3	1	2	3	4	1	2
o. dusty air	1	2	3	4	1	2	3	1	2	3	4	1	2
p. static electricity shocks	1	2	3	4	1	2	3	1	2	3	4	1	2

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All answers are STRICTLY CONFIDENTIAL

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CORNELL OFFICE ENVIRONMENTAL QUALITY SURVEY

Health

14. During the **PAST MONTH** how often have you experienced each of the following symptoms while working in this building?					15. Overall, during the **PAST MONTH** how much has your work been disrupted by this symptom?			16. What **TIME OF DAY** is this symptom usually experienced?				17. Are you **CURRENTLY** experiencing this symptom?		18. During the **PAST MONTH** what happened to this symptom at times you were away from work? (eg. evenings, weekends)		
					DISRUPTED											
Symptoms	Never	1 to 3 times a Month	1 to 3 times a Week	Almost every day	Not at all	Somewhat	Very	AM	PM	All Day	No Pattern	YES	NO	Got worse	Stayed the same	Got better
a. Dry eyes	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
b. Irritated, sore eyes	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
c. Tired, strained eyes	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
d. Sore, irritated throat	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
e. Dry skin	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
f. Hoarseness	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
g. Stuffy, congested nose	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
h. Runny nose	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
i. Excessive mental fatigue	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
j. Nervousness, irritability	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
k. Headache across forehead	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
l. Wheezing, chest tightness	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
m Nausea	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
n. Dizziness	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
o. Skin irritation, rashes	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
p. Diarrhea	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3
q. Unusual tiredness, lethargy	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3

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All answers are STRICTLY CONFIDENTIAL

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19. This section contains questions concerning the characteristics of your job. Please say how much you agree or disagree with each of the following statements about your job.

Job Characteristics	Strongly agree	Mostly agree	Uncertain	Mostly disagree	Strongly disagree
a. My job is usually interesting	1	2	3	4	5
b. I'm happy in my job	1	2	3	4	5
c. I dislike my job	1	2	3	4	5
d. I am satisfied with my job	1	2	3	4	5
e. I'm enthusiastic about my job	1	2	3	4	5
f. My job is rather monotonous	1	2	3	4	5
g. My job is not very stressful	1	2	3	4	5
h. I usually have to work fast	1	2	3	4	5
i. I often feel stressed at work	1	2	3	4	5
j. My job demands a lot of concentration	1	2	3	4	5
k. I often feel overworked	1	2	3	4	5
l. The office environment is satisfactory for my job	1	2	3	4	5

20. How often do you use the following at work?

	Several times a day	About once a day	3-4 Times a week	Less often	Never
a. Photocopier	1	2	3	4	5
b. Self copying/Carbonless copy paper	1	2	3	4	5
c. Correction fluid (specify below)	1	2	3	4	5

21. What is your job category?

Managerial	Professional	Technical	Clerical	Secretarial	Other:
1	2	3	4	5	6 (please specify)

22. About how many hours a day do you work with a computer or word processor?

Hours per day								
Never use	Less than 1	1	2	3	4	5	6	7 or more

All answers are STRICTLY CONFIDENTIAL

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CORNELL OFFICE ENVIRONMENTAL QUALITY SURVEY

General Information II-2

23. In an average working week (Monday - Friday), how many hours PER DAY are you exposed to other peoples' tobacco smoke?

	Never	Less than 1 hr	1-2hrs	3-4hrs	5-6hrs	7-8hrs	More than 8hrs
a. At home	1	2	3	4	5	6	7
b. At work	1	2	3	4	5	6	7
c. In Other Locations	1	2	3	4	5	6	7

24. In an average weekend, how many hours PER DAY are you exposed to other peoples' tobacco smoke?

	Never	Less than 1 hr	1-2hrs	3-4hrs	5-6hrs	7-8hrs	More than 8hrs
a. At home	1	2	3	4	5	6	7
b. In Other Locations	1	2	3	4	5	6	7

25. How bothersome are the following to you:

	Very Bothersome	Fairly Bothersome	Somewhat Bothersome	Not at all Bothersome
a. Seeing "No Smoking" Signs at work	1	2	3	4
b. Seeing tobacco smoke in the air in any place	1	2	3	4
c. Smelling tobacco smoke in the air in any place	1	2	3	4
d. The company's present smoking policy	1	2	3	4

26. How much time do you spend in the smoking area in these activities on an average day in total?

	Never	Less than 1/2 hr	1/2-1hr	1-2hrs	2-3hrs	More than 3 hrs
a. In meetings	1	2	3	4	5	6
b. Individual work	1	2	3	4	5	6
c. Other	1	2	3	4	5	6

IF YOU ARE A CURRENT OR FORMER SMOKER PLEASE COMPLETE THE APPROPRIATE SECTION

Former Smokers

27. How many years in total did you smoke?

Less than 1 yr	1-5yrs	6-10yrs	11-15yrs	16-20yrs	More than 20 yrs
1	2	3	4	5	6

28. About how much did you smoke EACH DAY:

	Cigarettes	Cigars	Pipe bowls
a. At WORK			
b. At HOME:			
c. At other places:			

29. How long ago did you stop smoking? ____ Years ____ Months

Current Smokers

30. How many years in total have you been smoking?

Less than 1 yr	1-5yrs	6-10yrs	11-15yrs	16-20yrs	More than 20 yrs
1	2	3	4	5	6

31. About how much do you smoke EACH DAY:

	Cigarettes	Cigars	Pipe bowls
a. At WORK			
b. At HOME:			
c. At other places:			

32. How accessible are the smoking areas to you?

Very accessible	Somewhat accessible	Not very accessible	Not at all accessible
1	2	3	4

33. How have your smoking habits been changed by the present smoking policy in your office?

	Smoke much more	Smoke slightly more	No change	Smoke slightly less	Smoke much less
At HOME	1	2	3	4	5
At WORK	1	2	3	4	5

Please write any comments on back of page

Thank you for completing this questionnaire *All answers are STRICTLY CONFIDENTIAL*

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APPENDIX 3

Example of a weekly diary card which will be modified and expanded to include a stress measure and possibly other measures described in the proposal

AIR QUALITY & SYMPTOM DIARY

PLACE SCORES

1 = Own office /desk
2 = Other part of building
3 = Cafeteria/ break room
4 = Other building
5 = Outside
6 = Own home
7 = Others home
8 = Own transport
9 = Public transport
10 = Other place

AIR QUALITY SCORES

1 = Not at all
2 = A little
3 = A lot

SYMPTOM SCORES

1 = None
2 = Mild
3 = Moderate
4 = Severe
5 = Very severe

Date: / /

MONDAY	TIME	PLACE	Too warm	Stagnant air	Dry air	Dusty air	Stale air	Odors	Irritated eyes	Irritated throat	Congested nose	Lethargy	Headache
Before work													
Mid-morning													
Lunchtime													
Mid-afternoon													
Early evening													
Late evening													

Date: / /

TUESDAY	TIME	PLACE	Too warm	Stagnant air	Dry air	Dusty air	Stale air	Odors	Irritated eyes	Irritated throat	Congested nose	Lethargy	Headache
Before work													
Mid-morning													
Lunchtime													
Mid-afternoon													
Early evening													
Late evening													

Date: / /

WEDNESDAY	TIME	PLACE	Too warm	Stagnant air	Dry air	Dusty air	Stale air	Odors	Irritated eyes	Irritated throat	Congested nose	Lethargy	Headache
Before work													
Mid-morning													
Lunchtime													
Mid-afternoon													
Early evening													
Late evening													

Date: / /

THURSDAY	TIME	PLACE	Too warm	Stagnant air	Dry air	Dusty air	Stale air	Odors	Irritated eyes	Irritated throat	Congested nose	Lethargy	Headache
Before work													
Mid-morning													
Lunchtime													
Mid-afternoon													
Early evening													
Late evening													

Date: / /

FRIDAY	TIME	PLACE	Too warm	Stagnant air	Dry air	Dusty air	Stale air	Odors	Irritated eyes	Irritated throat	Congested nose	Lethargy	Headache
Before work													
Mid-morning													
Lunchtime													
Mid-afternoon													
Early evening													
Late evening													

Date: / /

SATURDAY	TIME	PLACE	Too warm	Stagnant air	Dry air	Dusty air	Stale air	Odors	Irritated eyes	Irritated throat	Congested nose	Lethargy	Headache
Before work													
Mid-morning													
Lunchtime													
Mid-afternoon													
Early evening													
Late evening													

Date: / /

SUNDAY	TIME	PLACE	Too warm	Stagnant air	Dry air	Dusty air	Stale air	Odors	Irritated eyes	Irritated throat	Congested nose	Lethargy	Headache
Before work													
Mid-morning													
Lunchtime													
Mid-afternoon													
Early evening													
Late evening													

BIOGRAPHICAL SKETCH

Name:	Alan Hedge
Title:	Dr.
Education:	Bachelor of Science (1st Class Special Honors) Zoology. Subsidiary Physiology and Biochemistry, University of Sheffield, 1970.
	Master of Science, Zoology, University of Sheffield, 1971.
	Master of Science in Applied Psychology, Aston University, 1972.
	Doctor of Philosophy, Psychology, University of Sheffield, 1979.
Scientific field:	Human Factors (Ecological Ergonomics)
Major Research Interest:	Indoor environment research; indoor air quality; sick building syndrome; cognitive influences on environmental perception; stress and health
Research Projects:	The effects of smoking regulation and building ventilation on indoor air quality and employee comfort and health in offices.(1989-1994)

Selected Publications:

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Hedge, A. & M. D. Collis. (1987) Do negative air ions affect human mood and performance? Annals of Occupational Hygiene, 31, 285-290.

Hedge, A. (1987) Office Health Hazards: An annotated bibliography. Ergonomics, 30 ,(5), 733-772.

Hedge, A., Sterling, E. M. and T. D. Sterling. (1987) Building illness indices based on questionnaire responses. IAQ '86: Managing indoor air for health and energy conservation. Atlanta, ASHRAE, 31-43.

Robertson, A. S., Burge, P. S., Hedge, A., Sims, J., Gill, F. S., Finnegan, M., Pickering, C. A. C., & G. Dalton. (1985) Comparison of health problems related to work and environment measurements in two office buildings with different ventilation systems. British Medical Journal, 291, 373-376.

Hedge, A. (1984a) Suggestive evidence for a relationship between office design and self-reports of ill-health among office workers in the United Kingdom. Journal of Architectural and Planning Research, 1, (3), 163-174.

Hedge, A. (1984b) Ill health among office workers: An examination of the relationship between office design and employee well-being. In: E. Grandjean (ed.), Ergonomics and Health in Modern Offices, Taylor & Francis, pp. 46-51.

BIOGRAPHICAL SKETCH

Gary William Evans, Ph.D.

BIRTH: November 22, 1948

OFFICE: Design and Environmental Analysis
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EDUCATION:

Colgate University	1971	A.B., High honors in psychology
University of Massachusetts, Amherst	1973	M.S. Psychology
University of Massachusetts, Amherst	1975	Ph.D. Psychology
National Institute of Mental Health	1978	Neurobiology and Mental Illness
Karolinska Institute, Stockholm	1987-1988	Psychoneuroendo-crinology

HONORS AND AWARDS:

George Cobb Fellow	Colgate	1970
Phil R. Miller Psychology Prize	Colgate	1971
Who's Who in American Colleges and Universities		1971
Distinguished Teaching Assistant Award	University of Massachusetts	1974
NSF Dissertation Fellowship		1974-1975
Regents' Junior Faculty Fellowship	University of California	1977
Council for International Exchange of Scholars Fulbright Research Fellowship	University of Poona, India	1981-1982
Fellow of the American Psychological Association	(Divisions 9, 34)	1983
Who's Who in Frontier Science and Technology		1983
Who's Who in the West		1985
Alumni Association Distinguished Teaching Award	University of California, Irvine	1985
Society of Experimental Social Psychology		1986
Chancellor's Affirmative Action Award	University of California, Irvine	1987
International Fellow Swedish Work Environment Fund	Karolinska Institute, Sweden	1987-1988
Fellow of the American Psychological Society		1989

Academic Senate Distinguished Lectureship Award for Teaching | University of California, Irvine | 1992

SELECTED PUBLICATIONS: (greater than 100 publications)

Evans, G. W., & Howard, R. B. (1973). Personal space. Psychological Bulletin, 80, 334-344.

Evans, G. W. (1979). Behavioral and physiological consequences of crowding in humans. Journal of Applied Social Psychology, 9, 27-46.

Cohen, S., Evans, G. W., Krantz, D. S., & Stokols, D. (1980). Physiological, motivational and cognitive effects of aircraft noise on children: Moving from the laboratory to the field. American Psychologist, 35, 231-243.

Evans, G. W. (1980). Environmental cognition. Psychological Bulletin, 88, 259-287.

Cohen, S., Evans, G. W., Krantz, D. S., Stokols, D., & Kelly, S. (1981). Aircraft noise and children: Longitudinal and cross sectional evidence on adaptation to noise and the effectiveness of noise abatement. Journal of Personality and Social Psychology, 40, 330-345.

Evans, G. W., & Jacobs, S. V. (1981). Air pollution and human behavior. Journal of Social Issues, 37, 95-125.

Evans, G. W., Jacobs, S. V., & Frager, N. B. (1982). Adaptation to air pollution. Journal of Environmental Psychology, 2, 99-108.

Evans, G. W., Jacobs, S. V., Dooley, D., & Catalano, R. (1987). The interaction of stressful life events and chronic strains on community mental health. American Journal of Community Psychology, 15, 23-34.

Evans, G. W., Palsane, M. N., & Carrere, S. (1987). Type A behavior and occupational stress: A cross-cultural study of blue collar workers. Journal of Personality and Social Psychology, 52, 1002-1007.

Evans, G. W., Palsane, M. N., Lepore, S. J., & Martin, J. (1989). Residential density and psychological health: The mediating effects of social support. Journal of Personality and Social Psychology, 57, 994-999.

Evans, G. W., & Carrere, S. (1991). Traffic congestion, perceived control, and psychophysiological stress among urban bus drivers. Journal of Applied Psychology, 76, 658-663.

Lepore, S. J., Evans, G. W., & Palsane, M. N. (1991). Social hassles and psychological health in the context of crowding. Journal of Health and Social Behavior, 32, 357-367.

Lepore, S. J., Evans, G. W., & Schneider, M. (1991). The dynamic role of social support in the link between chronic stress and psychological distress. Journal of Personality and Social Psychology, 61, 899-909.

Evans, G. W., & Lepore, S. J. (in press). Household crowding and social support: A quasi-experimental analysis. Journal of Personality and Social Psychology.

Evans, G. W., Jacobs, S. V., & Frager, N. B. (1982). Behavioral responses to air pollution. In A. Baum & J. E. Singer (Eds.), Advances in environmental psychology, Vol. 3 (pp.237-270). Hillsdale, NJ: Erlbaum.

Evans, G. W., & Cohen, S. (1987). Environmental stress. In D. Stokols & I. Altman (Eds.), Handbook of environmental psychology (pp. 571-610). New York: John Wiley.

Evans, G. W. & Tafalla, R. (1987). Measurement of environmental annoyance. In H. Koelega (Ed.), Environmental annoyance: Characterization, measurement, and control (pp. 11-28). Amsterdam: Elsevier.

Evans, G. W., Johansson, G., & Carrere, S. (in press). Psychosocial factors and the physical environment: Inter-relations in the workplace. In C. L. Cooper & I. T. Robertson (Eds.), International review of industrial and organizational psychology. Chichester, U.K.: Wiley.

Evans, G. W. (Ed.). (1982). Environmental stress. New York: Cambridge University Press.

Cohen, S., Evans, G. W., Stokols, D., & Krantz, D. S. (1986). Behavior, health and environmental stress. New York: Plenum.

RESEARCH GRANTS & CONTRACTS:

Perceived control and environmental stressors. Roche Psychiatric Institute, Nutley, New Jersey.	1975-1976
Effects of prolonged noise exposure: A longitudinal study. National Science Foundation and National Institute of Environmental Health Sciences.	1977-1979
Behavioral effects of photochemical smog. Southern California Edison Company.	1978
Photochemical smog and mental health. Southern California Edison Company.	1979-1981

Relationship between ambient air quality and symptoms of respiratory disorder in a representative sample of the Los Angeles population. California Air Resources Board.	1981-1983
Coronary prone behavior and occupational stress. University of California Faculty Research Fellowship.	1983-1984
Human adaptation to isolated and confined environments. National Science Foundation and National Aeronautics and Space Administration.	1986-1987
Environmental cognition and assessment. National Science Foundation and Swedish Council for Building Research.	1987-1988
Computerization and life change: A psychophysiological study. Swedish Council for Research in the Humanities and Social Sciences.	1987-1989
Traffic congestion and the work environment of city bus drivers. National Science Foundation, Swedish Work Environment Fund and Swedish Transport Research Board.	1989-1993
Residential density and psychological health: The mediating effects of social support. National Science Foundation.	1990-1992
Chronic stress and the etiology of coronary heart disease. National Heart Lung and Blood Institute, Swedish Environmental Protection Board and Nordic Noise Council.	1990-1995

Editorial Review Boards

Representative Research in Social Psychology	1973-1975
Man-Environment Systems	1975-1982
Environmental Psychology and Nonverbal Behavior	1976-1979
Journal of Population and Environment	1981-1987
Handbook of Environmental Psychology	1982-1987
Advances in Environment, Behavior, and Design	1984-
Children's Environments Quarterly	1989-
Archives of Complex Environmental Studies	1989-
Journal of Environmental Psychology	1990-

Ad hoc Reviews

National Endowment for the Arts
National Institutes of Health
National Science Foundation
Social Science Research Council of Canada
Numerous Scholarly Journals

Membership in Professional Societies

American Psychological Association (Fellow)
American Psychological Society (Fellow)
Environmental Design Research Association
International Association of Applied Psychology
International Association of People and their Surroundings
International Society of Complex Environmental Studies
Society of Experimental Social Psychology
Society for Human Ecology
Society for the Psychological Study of Social Issues (Fellow)

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Personal

Born August 25, 1956. U. S. citizen.
Married. No children.

Education

Ph.D.	(Biometry),	Cornell University,	1987
Ph.D.	(Botany),	Cornell University,	1983
M.S.	(Botany),	Cornell University,	1981
Graduate study in Botany, University of California - Davis,			Fall, 1977
B.S.	(Biology),	Cornell University,	1977

Professional Experience

1988 - present Owner and primary statistical consultant for Gail Rubin Consulting, a statistical consulting firm in Ithaca, NY. Visiting Fellow at the Biometrics Unit, Cornell University, Ithaca, NY.

Spring 1990 Lecturer, Biometrics Unit, Cornell University, Ithaca, NY. I taught Stats. & Biom. 607, a nonparametric methods course geared towards graduate students in the natural and social sciences.

1987 - 1988 Senior Research Associate, NY State Agricultural Experiment Station, Geneva, NY and Cornell University, Ithaca, NY. I provided expertise in statistics and applied mathematics to the research departments at Geneva. I also participated in the Statistical Consulting Service of the Biometrics Unit, Cornell University.

Consulting Experience

1991 - present Statistical consultant for several projects investigating the effects of osteoarthritis drugs and surgical procedures on hip dysplasia in dogs. Dr. George Lust, Baker Institute, College of Veterinary Medicine, Cornell University, Ithaca, NY.

1991 - present	Statistical consultant for projects assessing the efficiency of power plant design in terms of number and mortality of fish passing through power plant turbines vs. fish shunts; testing the efficiency of fish shunts under different power plant operating conditions; comparing technologies for obtaining fish counts in different parts of the power plant. Barnes-Williams Environmental Consultants, Binghamton, NY.
1991	Statistical consultant for project investigating ecological memory of hayfields and the effect of imposing agricultural treatments on subsequent succession in hayfields. Alan Berkowitz, Institute of Ecosystem Studies, Cary Arboretum, Millbrook, NY.
1990 - 1992	Statistical consultant for research and development program on remediation of coal tar produced by defunct manufactured gas plants. Edward Neuhauser, Niagara Mohawk Power Corporation, Syracuse, NY.
1990 - 1991	Statistical consultant for a project comparing several technologies for remediating coal tar produced by defunct manufactured gas plants. David Nakles, Remediation Technologies, Pittsburgh, PA.
1989 - present	Statistical consultant for a project investigating the effects of smoking regulation and building ventilation on indoor air quality and employee comfort and health. Alan Hedge, Dept. of Design & Environmental Analysis, Cornell University, Ithaca, NY.
1989 - present	Statistical consultant for a project comparing accumulation of selenium and heavy metals in native vegetation and forage and root crops grown on coal flyash landfill and control sites. Leonard Weinstein, Boyce Thompson Institute for Plant Research.
1988 - 1991	Statistical consultant for a project, combining field surveys and controlled environment experiments, to investigate the effects of ozone pollution and acid precipitation on the anatomy, physiology and survival of red spruce. Robert Amundson and John Laurence, Boyce Thompson Institute for Plant Research.
1987 - 1988	Statistical modelling of the kinetics of migration of *Schistosoma*

mansoni, a parasite causing schistosomiasis, throughout the body of laboratory mice. Jay Georgi, Dept. of Microbiology, Immunology and Parasitology, College of Veterinary Medicine, Cornell University, Ithaca, NY.

1987 - 1988 Statistical modelling of the spread of several insect pests of cabbage through the growing season. Dept. of Entomology, NY State Agricultural Experiment Station, Geneva, NY.

1986 - 1986 Analysis of stratified sample survey data for Amy Hoogesteger: "Employee adjustment to physical changes in the office environment", M.S., Design & Environmental Analysis, Cornell University, August, 1986.

1985 - 1986 Statistical modelling of dose-response relationships for "Quantitation of Viral Pesticide Infectivity and Pathogenicity", a research project at Boyce Thompson Institute for Plant Research, Ithaca, NY. Also, comparison of response curves of leaf glutathione content through time for plants treated with different levels of sulfur dioxide; design of experiments testing the effects of sulfur dioxide and glutathione levels on insect-host interactions; design and analysis of insect feeding preference studies.

1985 - 1985 Analysis of an unbalanced factorial experiment testing the effects of core material and exposure conditions for Sham Mandaiker: "Mechanical behavior of small diameter aramid braids", M.S., Design & Environmental Analysis, Cornell University, August, 1985.

1984 - 1985 Statistical modelling of the fusion of nucleoli in cells of *Xenopus laevis.* Antonie Blackler, Section of Genetics and Development, Cornell University.

1984 - 1984 Design and analysis of factorial experiments testing the effects of protein level and aflatoxin dose and comparison of dose-response curves for George Dunaif: "The kinetic relationship between aflatoxin B_1 dose, dietary protein level and time of emergence of preneoplastic liver lesions in the rat", Ph.D., Environmental Toxicology, Cornell University, January, 1985.

1983 - 1984 Assessed statistical implications of blood pooling scheme, reviewed protocol, and determined appropriate statistical analyses

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for "Risk Factor Analysis of Dietary Constituents as Causes of Cancer" (China Project), a joint research program of the Division of Nutritional Sciences, Cornell University and the Chinese Academy of Preventive Medicine, Beijing, China. Also, developed computer coding of survey questionnaires.

1984 - 1986 Participated in the Biometrics Unit Consulting Service, Cornell University.

Scholarships and Honors

1983-present	Mu Sigma Rho, Statistical Honor Society
1982 - 1983	Cornell University Fellowship
1977	University of California-Davis Academic Achievement Scholarship
1974,'76,'77	Cornell University Deans List
1973-1977	New York State Regents Scholarship

Professional Societies

American Statistical Association
Biometric Society
Botanical Society of America
Institute for Mathematical Statistics

Reviewing of Statistics for Journals

Communications in Statistics
Communications in Statistics - Simulation and Computation
Canadian Journal of Plant Pathology
Evolution

Other Professional Service

Reviewing research proposals for NSF - Statistics and Probability section
Reviewer of undergraduate honors thesis in statistics and biometry, Cornell University.

Theses

Statistical distribution and estimation theory for a single server queue with fixed service time and complete balking, Ph.D., Biometry.
The control of sexual development in *Onoclea sensibilis*, Ph.D., Botany.

Publications

Rubin, G., D. Umbach, S. Shyu and C. Castillo-Chavez. 1992. Using mark-recapture methodology to estimate the size of a population at risk for sexually transmitted diseases. Statistics in Medicine 11: 1533-1549.

Arthur, M.A. and G. Rubin. 1992. Sample size requirements for estimating biomass production in an Engelmann spruce, subalpine fir forest. Canadian Journal of Forest Research (submitted).

Arthur, M.A., Rubin, G., Woodbury, P.B., and L. Weinstein. 1992. Gypsum amendment to soil can reduce selenium uptake by alfalfa grown in the presence of coal fly ash. Plant and Soil 148: 83-90.

Arthur, M., R.E. Schneider, L.H. Weinstein and G. Rubin. 1992. Uptake and accumulation of selenium by terrestrial plants growing on a coal fly ash landfill: part 1. Corn. Environmental Toxicology and Chemistry 11: 541-547.

Arthur, M., G. Rubin, P.B. Woodbury, R.E. Schneider and L.H. Weinstein. 1992. Uptake and accumulation of selenium by terrestrial plants growing on a coal fly ash landfill: part 2. Forage and root crops. Environmental Toxicology and Chemistry 11: 1289-1299.

Arthur, M., G. Rubin, R.E. Schneider and L.H. Weinstein. 1992. Uptake and accumulation of selenium by terrestrial plants growing on a coal fly ash landfill: part 3. Forbs and grasses. Environmental Toxicology and Chemistry 11: 1301-1306.

Cumming, J.R., R.G. Amundson, S. Fellows and G. Rubin. 1992. Ozone potentiates winter injury differentially in red spruce provenances. New Phytologist (submitted).

Hedge, A., W.A. Erickson and G. Rubin. 1992. Effects of personal and occupational factors on sick building syndrome reports in air conditioned offices. In J.C. Quick, L.R. Murphy and J.J. Hurrell, Jr. (eds.) Stress and Well-being at Work: Assessments and Interventions for Occupational Mental Health, American Psychological Association, pp. 286-298.

Lust, G., A.J. Williams, N. Burton-Wurster, K.A. Beck and G. Rubin. 1992. Effects of intramuscular administration of glycosaminoglycan polysulfates on signs of incipient hip dysplasia in growing pups. American Journal of Veterinary Research 53: 1836-1843.

Castillo-Chavez, C., S. Shyu, G. Rubin and D. Umbach. 1992. On the estimation problem of mixing/pair formation matrices with applications to models for sexually-transmitted diseases. In N. P. Jewell, K. Dietz and V. T. Farewell (eds.) AIDS Epidemiology: Methodological Issues, Birhauser, Boston, pp. 384-402.

Hedge, A., W.E. Erickson and G. Rubin. 1991. The effects of smoking policy on indoor air quality and sick building syndrome in 18 air-conditioned offices. In IAQ '91 - Healthy Buildings , ASHRAE, Atlanta, pp. 151-159.

Hedge, A., W.E. Erickson and G. Rubin. 1991. VDT use, job stress, job satisfaction and the sick building syndrome in offices. In Y. Queinnec & F. Daniellou (eds.) Designing for Everyone, Proceedings of the 11th Congress of the International Ergonomics Association, Taylor & Francis, Paris, vol. 1, pp. 713-715.

Hedge, A., W.E. Erickson and G. Rubin. 1991. Smoking policy, indoor air quality and sick building syndrome in offices. (Abstract) British Occupational Hygiene Society Annual Conference, Nottingham, U.K.

Paolillo, D.J., Jr. and G. Rubin. 1991. Relative elemental rates of elongation and the protoxylem-metaxylem transition in hypocotyls of soybean seedlings. American Journal of Botany 78: 845-854.

Rubin, G., C.E. McCulloch and M. Shapiro. 1990. Multinomial runs tests to detect clustering in constrained free recall. JASA 85: 315-320.

Rubin, G. and D.S. Robson. 1990. A single server queue with random arrivals and balking: confidence interval estimation. Queueing Systems 7: 283-306.

Amundson, R.G., R.G. Alscher, S. Fellows, G. Rubin, J. Fincher, P. van Leuken and L.H. Weinstein. 1990. Seasonal changes in the pigments, carbohydrates and growth of red spruce as affected by exposure to ozone for two growing seasons. New Phytologist 118: 127-138.

Hedge, A., W.A. Erickson and G. Rubin. 1990. Building ventilation and smoking policy effects on indoor air quality and employee comfort and health. Indoor Air '90, Proceedings of the 5th International Conference on Indoor Air Quality and Climate, Toronto, Canada, vol.1, pp. 739-744.

Weinstein, L.H., M. Richmond, E.W. Wischusen, R.E. Schneider, A.O. Beers and G.

Rubin. 1990. Uptake and accumulation of selenium by plants growing on a coal fly ash landfill. Proceedings of the 4th International Conference on Environmental Contamination, Barcelona, Spain, pp. 230-232.

Alscher, R.G., R.G. Amundson, J.R. Cumming, S. Fellows, J. Fincher, G. Rubin and L. Weinstein. 1989. Seasonal changes in the pigments, carbohydrates and growth of red spruce as affected by ozone. New Phytologist 113: 211-223.

Fincher, J., J.R. Cumming, R.G. Alscher, G. Rubin and L. Weinstein. 1989. Long-term ozone exposure affects winter hardiness of red spruce seedlings. New Phytologist 113: 85-96.

Rubin, G. and D.S. Robson. 1988. Interval estimation for a single server queue with Poisson arrivals and complete balking. (Abstract) Proceedings of the XIV International Biometrics Conference.

Seem, R.C., G. Rubin and C.M. Becker. 1988. Duration of leaf wetting and drying periods in orchards. (Abstract) APS Abstracts, The American Phytopathological Society.

Rubin, G., D.S. Robson and D.J. Paolillo, Jr. 1985. Effects of population density on sex expression in *Onoclea sensibilis* L. on agar and ashed soil. Ann. Bot. 55: 205-215.

Rubin, G. and D.J. Paolillo, Jr. 1984. Obtaining a sterilized soil for the growth of *Onoclea* gametophytes. New Phytol. 97: 621-628.

Rubin, G. and D.J. Paolillo, Jr. 1982. Development of sexuality in *Onoclea* in soil culture. Botanical Society of America, Misc. Publ. No.162. (Abstract)

Paolillo, D.J., Jr. and G. Rubin. 1980. Reconstructions of the grana-fretwork system of a chloroplast. Amer. J. Bot. 67: 575-584.

Rubin, G. and D.J. Paolillo, Jr. 1978. Vascular and general anatomy of the root-stocks of three stemless *Viola* species. Ann. Bot. 42: 981-988.

Rubin, G. and M. Zaitlin. 1976. Cell concentration as a factor in precursor incorporation by tobacco leaf protoplasts or separated cells. Planta 131: 87-89.

Technical Reports

Meredith, M.P. and G. Rubin. 1990. Some useful reparameterizations: linear to nonlinear models. Technical Report #BU-1070-M in Biometric Series, Cornell University, Ithaca, NY.

Rubin, G. and D.S. Robson. 1989. Estimation theory for a single server queue with random arrivals and complete balking. Technical Report #BU-1020-M in Biometric Series, Cornell University, Ithaca, NY.

Manuscripts in Preparation

Rubin, G. and J. Laurence. 1993. A model for estimating effective daily ozone dose in plants from atmospheric ozone level and vapor pressure deficit. Technical Report #BU-1035-M in Biometric Series, Cornell University, Ithaca, NY.

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